N.A.Gvozdetsky

SOVIET GEOGRAPHICAL EXPLORATIONS AND DISCOVERIES

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СОВЕТСКИЕ ГЕОГРАФИЧЕСКИЕ ИССЛЕДОВАНИЯ И ОТКРЫТИЯ

На английском языке

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PREFACE

The origins of geography as a science go back to antiquity. At first, it concerned itself with the description of various parts of the world, of near and distant countries. Hence the name "geography", that is, "description of the Earth" (from the Greek *geo*, meaning "earth", and *grapho*, "I write"). Geographers and travellers gradually penetrated every corner of the Earth and plotted all the explored areas on geographical maps. Eventually, very few unexplored places remained, and geography went over increasingly from fact gathering and description to the interpretation and explanation of the arrangement of things observed on the Earth's surface.

An important contribution to the development of modern geography was made at the turn of the century by the great Russian naturalist V. V. Dokuchayev when he introduced his concept of nature's oneness, of the genetic, eternal and natural relationship between the forces, bodies and phenomena of inanimate and animate nature.

Modern geography necessarily involves making a deep analysis of the relationships among the phenomena of nature and of the economic life of human society. In studying these relationships, geographers make increasingly wide use of the advances made in such fields of knowledge as physics, chemistry, biology, geology, geophysics, geochemistry and the mathematical, technical and social sciences.

With its new and exact methods of research, modern geography now has little in common with the former descriptive geography. The main emphasis in geographic research is now on studying the natural environment, with all of its

interconnections and specific aspects, studying the natural resources of specific areas and determining the most rational methods of utilising them, and studying the geographic distribution of production in relation to natural and economic factors. The first group of tasks lies within the province of physical geography, and the second is the special concern of economic geography.

Is there, however, anything left for today's geographers to discover on our planet? Unquestionably there is. Discovery is still one of the fascinating aspects of this science. Nature holds many unknowns; in fact, there are still some unknowns even concerning the very face of the Earth, concerning the planet's large geographical features—features that appear not only on specialised maps of nature but on ordinary maps of the world. In the 1930s, the eminent Soviet geologist and geographer, S. V. Obruchev, wrote the following about his aerial observations of the regions in the far north-east of Asia, which had at that time not yet been thoroughly studied, nor mapped precisely: "It is fascinating to observe how geographic elements (mountain ranges, rivers, lakes—*N.G.*) that are drawn so clearly and definitely on maps, change and turn into entirely different forms" [1]*. The northeastern extremities of our country have now been studied much more completely and are accurately depicted on maps. But there are still places in the world about which we have an insufficiently accurate notion.

There is still plenty of work to be done not only in the specialised areas of geographic research, but also in the field of geographical exploration and discovery. This applies particularly to the Arctic, the Antarctic and the ocean depths, the conquest of which man is accomplishing now with ever greater success with the help of his rapidly advancing technology.

The present book takes a look into the research carried on by geographers and explorers during the years since the establishment of Soviet power in our country. It is impossible, of course, to cover in a single book all of the multifaceted geographic research done by Soviet scholars both at home and abroad. Our book, consequently, focusses primarily on expeditionary research leading to geographic

* See Bibliography at the end of the book.

discoveries that introduced substantial changes in the maps of the USSR and the world, eliminating some of the "blank spaces" previously found thereon.

Until fairly recently, there were many such blank spaces on the maps of the USSR and the world, that is, land and water areas that had not been studied and therefore either not shown on the map at all or shown inaccurately.

What vast natural resources every such blank space might conceal! Mountain ranges abound in ore, valuable timber and swift mountain torrents, the potential source of cheap energy; wide-stretching plains are rich in forests, pastures, hayfields and fertile tracts, various kinds of minerals, rivers, lakes and subterranean waters; and the ocean is rich in food fauna and minerals. To reveal the secrets of unexplored territories and water areas, to chart them on a map, to study nature's riches and place them at the service of mankind—such is the task of the geographic explorer.

This book tells about how Soviet explorers and geographers have penetrated the secrets of unexplored land and water areas and how they have filled in many blank spaces on the map.

The book consists of two parts, the first dealing with exploration and discovery within the Soviet Union. The second part is devoted to Soviet explorations and discoveries in foreign countries, in the Antarctic and deep below the surface of the World Ocean.

The first part of the book deals almost exclusively with discoveries that have helped to fill in blank spaces on the general geographic map. The second part, while following the same basic idea as it describes exploratory journeys abroad, also touches in passing on various aspects of studying the nature of the land and water regions explored. But only in passing, for the author's basic task in writing this book did not include this kind of discussion. There was always the temptation to say more than space actually permitted, for the subject is vast and inexhaustible.

The present book is not a handbook of Soviet geographical exploration and discovery, nor a compendium presenting all the data on the subject dealt with. The author attempted to include as many facts as possible, but it was not his objective to make an exhaustive job of it.

The author felt that to write about everything in equal measure or even in proportion to the significance of the

exploratory work described would result in a tedious book. Some things therefore are only mentioned in order to round out the subject, while others are gone into in more detail and made to stand out against a general background, as for example, when the more significant discoveries are discussed. Using concrete examples from the work of certain expeditions, the author has tried to show the difficult conditions under which the explorer must work.

EXPLORATIONS AND DISCOVERIES WITHIN THE SOVIET UNION AND IN THE SOVIET ARCTIC

CHAPTER 1

A LOOK INTO THE PAST AND AN OVERVIEW OF EXPLORATION IN THE YEARS OF SOVIET POWER

Our country is our house. To know your house, your country, you must first of all have a good picture of it on a map.

L. S. Berg

The territory of the Soviet Union is varied in nature and its riches are inexhaustible.

In the severe, icebound arctic expanses glaciers perch like huge caps on the islands of Severnaya Zemlya and Novaya Zemlya, while in the south, in the deserts of Central Asia, the sun beats down unmercifully, heating the soil to 60°C, and sometimes to almost 80°, forcing many animals to hide in their burrows from the deadly heat.

The dreary semi-desert and desert plain of the Transcaspian lowland lies below sea level, while the proud snowy peaks of the Caucasus, the Pamirs and Tien Shan rise up 5 to 7.5 km into the sky. High in the mountains it is a world of cold, ice and snow, with glaciers of up to 60-77 km in length flowing down along the mountain valleys. Streams of water issuing from them irrigate the desert plains and arid steppes, give life to plants and harbour huge reserves of hydraulic energy. Greedily absorbing the life-giving moisture, the finest varieties of cotton and other heat-loving crops thrive in the desert plains of Central Asia.

The cold mountain deserts of the eastern Pamirs and the Interior Tien Shan are grim and barren; many parts of the sun-scorched plains of Central Asia are almost lifeless; and the semi-desert expanses of eastern Transcaucasia are bleak, with their sparsely distributed shrubs of wormwood,

solyanka and camel's thistle on the sun-scorched argillaceous plain, now giving way to vast cotton fields. But on the western slopes of the Caucasus mountains descending to the Black Sea coast grow luxuriant subtropical forests, where it is difficult to make one's way through the dense undergrowth of evergreen shrubs or through the liana interweaving the trees at the edge of the forest. Here, tea is grown, citrus trees abound, and along the shore of the Black Sea palm trees thrive even in winter. The lower belt of the Talysh mountain slopes, covered by subtropical forests, is similar, while at the foothills in the Lenkoran coastal region we find emerald rice fields and a landscape resembling the islands of Indonesia.

Endless steppes; rocky mountain gorges; dense taiga, where the eye sometimes cannot see beyond a few metres into its depths; the steely waters of the northern seas and the azure waters of the south; roaring mountain cascades and calm, majestic rivers, sometimes reaching tens of kilometres in width, flowing through the plains—such are the contrasts of nature on the vast territory of the USSR occupying one-sixth of the inhabited land area of the world.

And everywhere there are either minerals, or fertile soil, or forests, or pastures and hayfields, or valuable fur-bearing animals, or fish, or water power resources, or other natural riches.

To reveal all of the country's diverse natural resources, it had to be explored and, above all, the geographic map had to be corrected and the blank spaces on it filled in.

* * *

Exploration of the remote regions of the USSR began long ago.

After the Cossack ataman Yermak's expedition east of the Urals (16th century), Russian possessions expanded rapidly. In their search for fur-bearing animals and new land, the Cossacks crossed all of Siberia from west to east in an extremely short period of time—about 60 years.

The first Russian explorers reached the Pacific Ocean in 1639, when a detachment of soldiers under Ivan Moskvitin explored the coastline of the Sea of Okhotsk. Six years later, Vasili Poyarkov's detachment sailed the Sea of Okhotsk, entering it on small river vessels from the mouth of the

Amur River. "This heroic journey made by intrepid men of yore along an unknown river and over a cold unchartered sea cannot help but evoke our amazement," wrote Academician L.S. Berg about Poyarkov's journey [2].

Over 300 years ago (in 1648), Semyon Dezhnev and Fedot Popov accomplished an unparalleled feat in the remote and severe waters of the far north-east when they rounded the northeastern extremities of Asia by sea. The seafarers had made a great geographical discovery, apparently without realising it themselves—the discovery of the strait between Asia and America. After Dezhnev and his group, many Russian Cossacks and merchants made bold voyages in the waters off the shores of eastern Asia.

At the end of the 17th century, Vladimir Atlasov, an official of the Anadyr post, returned to Anadyr after spending two years on the Kamchatka Peninsula. He was the first to give a detailed account of the geographical features of Kamchatka. Forty years later, Kamchatka was explored again by the Russian scholar and member of the Second Kamchatka Expedition, S. P. Krasheninnikov.

Russian navigation in the Arctic Ocean began long, long ago, and in the 16th and 17th centuries, Russians in the coastal regions were expert navigators and shipbuilders.

Finds made by Soviet hydrographers in 1940 and 1941 on the Island of Faddei and on the shores of the Taimyr Peninsula (the Gulf of Sims), and also archeological exploration in the same places in 1945, established the fact that in the early 17th century (not later than 1617) Russian seafarers sailing from west to east had rounded the northernmost point of Asia, the Cape of Chelyuskin.

The Great Northern Expedition, which began in 1733, comprises a whole epoch in the history of geographic exploration. Four detachments, each sailing on two ships, set out to explore the northern shores of Siberia and the mouths of the Northern Dvina, Ob, Yenisei and Lena rivers. The names of the men taking part in that grandiose and difficult undertaking—Muravyov, Pavlov, Malygin, Skuratov, Ovtsyn, Minin, Pronchishchev, Lasinius, the brothers Khariton and Dmitri Laptev, Chelyuskin—have gone down in the history of science and many of them appear on today's maps. The ten years of work done by the Great Northern Expedition produced a survey of almost the entire northern seaboard of Russia. Up until the beginning of the 20th

century, maps of the northern coast of Siberia were based on the accurate data collected by that expedition.

Explorations made by Academician K. M. Ber in Novaya Zemlya (1837) and Academician A. F. Middendorf in Taimyr (1843) played an important role in the geographical study of the Arctic.

Exploration also went on in the south of the country. The systematic advance of Russians into the Caucasus began under Peter the Great, and it was then that the first special scientific exploration and mapping of the Caucasian shoreline of the Caspian Sea and the neighbouring mountain regions of the Caucasus were carried out.

In the 1830s and 1840s, the outstanding Georgian scholar, Vakhushti Bagrationi drew up two sets of maps of the greater part of the Caucasus. He based both sets of maps on Georgian topographical surveys and descriptions, but in the second set he also incorporated data from Russian surveys.

A Russian scientific expedition explored Mt. Elbrus in 1829. In 1850, geodesist I.I. Khodzko ascended Mt. Ararat with a large expedition to make geodetic observations. He remained on the summit for a week, using a tent buried in the snow for shelter. And in the 1880s, the high mountain region of the Caucasus was surveyed with instruments.

Between 1856 and 1880, several eminent Russian explorers, among them P. P. Semenov, N. A. Severtsov, A. P. Fedchenko and I. V. Mushketov, penetrated into the distant mountain regions of Central Asia.

Kazakh scholar and traveller Ch. Ch. Valikhanov took an active part in drawing up maps of Central Asia and Kazakhstan.

The interior region of European Russia and Siberia was studied by many expeditions organised by the Russian Academy of Sciences, the Russian Geographical Society, which was founded in 1845, and other establishments.

In 1889, Russian geodesist and cartographer A. A. Tillo completed a hypsometric map* of European Russia (excluding its northern part). The map showed the actual location and contours of the major highlands and lowlands of European Russia.

Discovery followed discovery in the Asiatic part of Russia, and new peaks, glaciers, depressions, lakes and

* A hypsometric map is one on which varying elevations on the Earth's surface are indicated by colour shadings.

rivers were continually added to the map. The blank spaces were gradually being filled in.

Exploration of the outlying regions continued. In 1908-1909, a big expedition organised with the help of the Russian Geographical Society completed the pre-revolutionary stage of exploration on the Kamchatka Peninsula. An excellent description of Kamchatka was compiled by botanist and geographer V. L. Komarov, one of the members of the expedition.

In 1913, a hydrographic expedition, headed by hydrographer B. A. Vilkitsky, sailed on two ships, the *Taimyr* and the *Vaigach*, through the eastern part of the Arctic Ocean exploring the water area between the Cape of Chelyuskin and the Bering Strait, a distance of about 4,500 kilometres. The greatest geographical discovery of the first quarter of the 20th century was made at that time—the discovery of the large islands of Severnaya Zemlya. As it turned out, the Russian sailors discovered the last big tract of land in the world.

Thus it was that Russian explorers, at first the Cossacks and merchants, and later geographers, geodesists, geologists and other specialists, gradually accumulated information about Siberia and the Far East, the icy expanses of the Arctic, the Caucasus and Ural mountains and the deserts and mountains of Central Asia. Their inquisitiveness and their selfless efforts under difficult conditions in remote unsettled areas contributed much to geographic knowledge. Neither the cold and snowstorms, nor the heat and lack of water, nor the dangerous fords of mountain rivers held them back.

* * *

However great the achievements of the heroic explorers of pre-revolutionary times may have been, by the time of the Great October Socialist Revolution, very many blank spaces still remained on the map of Russia. Within the country, especially in Eastern Siberia, in the northern Siberian tundras and in Central Asia, lay vast expanses of unexplored land. And many islands in the polar waters still awaited discovery.

This was inevitable because tsarist Russia showed little interest in developing her remote outskirts economically,

and so was not motivated to make a comprehensive study of those regions. In pre-revolutionary times geographic exploration was conducted at the personal initiative of scientists and other progressive individuals, especially by members of the Russian Geographical Society. Frequently, funds to finance exploratory expeditions came from private sources and sometimes even from contributions made by the public (as in the case of G. Sedov's expedition to the North Pole, and others).

Expeditionary exploration did not, and could not receive much-needed government support. The limited funds released by government agencies for certain expeditions in which the tsarist regime was for one reason or another interested were not enough to ensure a broad programme of exploratory work.

The Great October Socialist Revolution, however, opened the way for the kind of systematic and comprehensive study of the country necessary to reveal all of its bounteous natural riches. The young Soviet republic experienced many difficult years of economic dislocation and civil war, but even during those trying times, the Party and the Government began organising the geographic study of the country.

In 1918, at Lenin's instructions, a number of expeditions were organised to study the productive forces of Soviet Russia. These included various expeditions aimed at finding new routes, expeditions to determine appropriate sites for building hydrotechnical installations and others. Topographical surveys were made and new maps drawn up.

That same year, the Council of People's Commissars approved a plan for geological exploration.

On July 2, 1918, Lenin signed a Soviet Government decree allocating one million rubles for the organisation of the Arctic Ocean Hydrographic Expedition to study the water areas of the Soviet Arctic. Geological expeditions were sent to the Arctic at the same time.

In his famous "Draft Plan of Scientific and Technical Work" [3] (April 1918), Lenin provided the Academy of Sciences with guidelines for the study of the country's productive forces. On March 15, 1919, he signed a decree establishing the Chief Geodetic Administration "to conduct a topographical study of the territory of the RSFSR with the aim of raising and developing the productive forces of the country...." [4].

The Soviet Government's programme of exploring the remote regions of the country, including the Arctic, was temporarily interrupted by the invasion of foreign interventionists who seized the northern areas of European Russia and occupied Siberia and the Far East. But as soon as any northern area was liberated, its study and development was resumed. In 1920, expeditions were sent to the White Sea and the mouths of the Siberian rivers Ob, Yenisei and Lena.

On April 20, 1920, the Siberian Revolutionary Committee established a special Northern Sea Route Committee charged with studying, equipping and improving the Northern Sea Route with the aim of making it a permanent and practical communications artery. That same year, the Council of People's Commissars allocated 41.3 million rubles for a project designed to ensure safe navigation in the waters of the Arctic Ocean.

In 1921, the First Kara Sea Expedition was outfitted, and research in hydrography was further developed. The Supreme Economic Council organised the Northern Scientific and Commercial Expedition, whose functions were later taken over by the Arctic Institute. The Russian Geographical Society set up a Committee on the North.

On March 10, 1921, Lenin signed a decree of the Council of People's Commissars on the organisation of a Floating Marine Research Institute (Plavmorin) "for a comprehensive and systematic exploration of the Northern seas, their islands and coastlines...". The institute, according to the decree, was to be provided with fuel, equipment and provisions "on a level with establishments of primary state importance" [5].

The Floating Marine Research Institute's first expedition took place in 1921, on the icebreaker *Malygin*. Subsequent voyages were made on the *Persei*, which was launched in 1922, on the fifth anniversary of the Great October Socialist Revolution. In addition to the Northern Scientific and Commercial Expedition and the expeditions of the Floating Marine Research Institute, exploration of the North was conducted by the Hydrographic Administration and the Russian Institute of Hydrology. In these first years of the young Soviet republic's existence, "scientific work in the Arctic assumed a scope broader than ever before seen in the history of polar exploration" [6].

In 1920, expeditions to the Kola Peninsula and the gulf of Kara Bogaz Gol were organised by the Permanent Commission for the Study of Natural Productive Forces, which had been established in the Russian Academy of Sciences during the First World War. The second expedition was sent at direct instructions from Lenin.

The personal attention that Lenin gave to the problem of studying the country's natural resources lent tremendous impetus to the Academy of Sciences' work in this sphere. "Only 1918-1919," wrote A. E. Fersman, "awakened the Academy of Sciences to new creative effort. On Lenin's instructions, material lying in the Commission for the Study of Natural Productive Forces was quickly published. Sizeable funds were allocated, and the Academy began to expand its expeditionary activity" [7].

As the young Soviet republic grew stronger and stronger in its victorious struggle against external and internal enemies, the work of exploring and studying its huge expanses went on vigorously. Its geographical features and its mineral and water resources were subjected to extensive study. Expeditions penetrated into the deserts and mountains of Central Asia and into the distant northeastern regions of Siberia.

On the occasion of its 200th anniversary in 1925, the Russian Academy of Sciences was renamed the Academy of Sciences of the USSR. This expanded the Academy's sphere of activity and had a marked effect on its subsequent expeditionary work, since it became directly responsible for exploration in the remote national republics. The Academy established in 1926 a Special Committee on Exploration in the Union and Autonomous Republics (shortly thereafter reorganised into the Committee on Expeditionary Exploration), and other committees were set up to study the individual republics. These years saw the beginning of extensive explorations of Yakutia, the Kara Kum desert, Lake Sevan in Transcaucasia, and, somewhat later, of the Pamirs. The study of the Arctic region continued with expeditions working in Novaya Zemlya, the New Siberian Islands and the northern reaches of the Yenisei. New polar stations and ports came into being. The Northern Sea Route Committee and the Standing Polar Committee of the Academy of Sciences of the USSR conducted important geographic research in the Arctic.

On July 31, 1928, the Council of People's Commissars passed a resolution to form a governmental Arctic Commission, giving even greater importance to Arctic studies since the development of that region as well as other remote areas was now included in the country's overall economic plan.

The Chief Northern Sea Route Administration (Glavsevmorput) was set up in 1932 to handle the important job of organising the comprehensive study and development of the northern seas and their adjacent maritime regions, also necessarily involving the study of the central parts of the Arctic.

An Arctic Institute expedition in 1932, headed by O. Y. Schmidt and conducted on the icebreaker *Sibiryakov*, made the first voyage without a winter layover from Arkhangelsk to the Bering Strait, proving the feasibility of using the Northern Sea Route. Through-voyages over the route were later repeated on the *Chelyuskin* in 1933 and the *Litke* in 1934 (the icebreaker *Litke* traversed the Northern Sea Route in the opposite direction—from Vladivostok to Murmansk). Cargo ships began coursing this polar route in 1935.

The scientists, sailors and airplane pilots who explored the Soviet sector of the Arctic have added many a glorious page to the history of geographical discovery and exploration. The courage displayed by Soviet people in studying and conquering the icy Arctic expanses was acknowledged when the honorary title of Hero of the Soviet Union was first awarded to the flyers taking part in rescuing the *Chelyuskin* party in 1934.

The Geodetic Administration, the All-Union Geological Prospecting Administration and the Academy of Sciences of the USSR continued to expand their expeditionary work. While the Academy of Sciences had sent off 50 expeditions in 1927, its expeditionary activity assumed an even grander scale after the organisation in 1930 of the Council on Productive Forces Research. It sent many large, joint expeditions into little-explored regions of the country to help solve major economic problems connected with socialist construction. Expeditions in 1932 involved over 600 scientists in over 30 fields, organised into 140 detachments.

When one thinks of the richly supplied and equipped Soviet expeditions (expeditions into the high polar latitudes, into the deserts and mountains of Central Asia, and to the taiga expanses of Siberia), with their airplanes,

trucks, motor launches, radio equipment, etc., one cannot help but recall under what extremely difficult conditions the first Russian explorers had to operate. But even today, expeditions in the mountains, in the taiga or the severe Arctic regions have to cope with many hardships and dangers.

The routes followed by expeditions setting out from Leningrad, Moscow and other cities form a dense network over the territory of the country. Expeditions have penetrated into the distant Siberian tundra and into deserts once considered inaccessible, climbed the highest mountain ridges and probed the bowels of the earth with boring equipment. Even to the bottom of the sea the scientists went, dressed in diving suits.

No hardship or danger prevented the explorers from accomplishing their set task. There have been cases when explorers have risked and even lost their lives to save the field materials of their expeditions.

In places where Soviet explorers have passed, enterprises of socialist industry have sprung up and entire areas have changed beyond recognition. In once remote outskirts of the country, centres of culture have blossomed. With the fraternal help of the Russian people, the outlying national areas developed. In the Union and Autonomous republics, along with the economic upsurge, national science and culture began to flourish. Scientific and industrial research organisations were established and began studying the natural resources and geographical features of the territory.

In the exploration of the deserts and mountains of Central Asia, for example, an important role was played by the Central Asian State University (in Tashkent), which was founded in the first years of Soviet power at Lenin's initiative. Branches of the USSR Academy of Sciences, later reorganised into academies of sciences of the Union republics, also conducted important explorations in Central Asia, Transcaucasia and other outlying national areas. As the years went by, an ever greater part in this work was taken on by local national cadres of scientists trained since the establishment of Soviet power.

The study of the country's national resources was not interrupted by the Great Patriotic War, but it was to a large extent subordinated to interests of defence. Soviet scientists shared a single goal—to give everything necessary to

In the Alai Range

the front. Cartographic work, the search for raw materials and the study of other natural resources went on at an accelerated pace.

Expeditionary work assumed an unprecedented scope in the post-war years. New challenges in this field arose in connection with the development of arid lands, the construction of the Lenin Volga-Don Canal and the gigantic hydropower systems on the Russian (East European) Plain, the harnessing of the energy of the mighty Siberian rivers and the further study of the Arctic and the Far Eastern seas. Great progress was made in developing virgin and long-fallow lands, especially in Kazakhstan and in the southern part of Western Siberia.

Large-scale projects were launched to transform nature in various areas through drainage, irrigation and other means. Such work went on in the Crimea and the Caucasus, in the Central Asian republics and Kazakhstan, in southern Siberia and elsewhere, and was, of course, always preceded by scientific exploration.

Back in 1937, the eminent Soviet geographer, A. A. Borzov, wrote: "...The approach to the natural environment

in the USSR is fundamentally different from the approach taken in the capitalist world: the planned and scientifically justified exploitation of nature's forces requires a full and complete knowledge of those forces based on comprehensive all-inclusive study, and does not tolerate the practice of using certain specific resources without taking into account the effect this has on the entire geographical environment. We want least of all to live at the expense of future generations, and desire not only to avoid impoverishing them but to actually enrich them as much as possible, to pass on our country to them thoroughly and deeply studied and organised in complete correspondence with this systematic and strictly scientific study" [8].

In this study of natural features and conditions, Soviet geographers and other specialists may deal with huge tracts of land and with relatively small territories such as those of individual state or collective farms. An extensive programme of geographic exploration is underway in still largely unsettled, newly developing areas, as for example in Western Siberia, especially in Tyumen Region.

* * *

Through the combined efforts of geodesists, topographers, cartographers and geographers, vast areas of the country have been surveyed and mapped over the years of Soviet power. On the basis of Soviet topographical and aerophotographical surveys, the maps of many regions have been completely revised. The wide use of aerophotographical surveying and new data processing methods have made it possible to do this kind of work very rapidly. Within the USSR there are virtually no more blank spaces, that is, areas that have not been subjected to cartographical exploration. What remains to be done in some places, perhaps, is to fill in certain details on large-scale maps.

When one considers the size of the country and the large number of blank spaces on the maps of Russia that existed in the pre-revolutionary period, then one can appreciate the tremendous work done in Soviet times. Areas larger than the biggest countries of Western Europe were explored and studied for the first time.

Large blank spaces were eliminated; the directions of mountain ridges, contours of seacoasts and the

course of rivers were corrected, and many mountains and depressions, glaciers, rivers, lakes and other geographical features were mapped for the first time.

The most significant discoveries and alterations in the map of the USSR are indicated on the map found between pages 36 and 37 of this book. The map reflects, and the following chapters of the book discuss, primarily those results of exploration that have produced noticeable changes in the general map of the country.

It goes without saying that in the course of exploration studies were made of the bowels of the earth, the soil, vegetation, the relief configurations, climate, the water resources and the landscape; new natural resources were brought to light and many special maps were drawn up and comprehensive atlases compiled.

CHAPTER 2

CHANGES ON THE MAP OF THE ARCTIC. DISCOVERY OF SEVERNAYA ZEMLYA AND THE ISLANDS OF THE KARA SEA. EXPLORATION OF THE LARGE ARCTIC ISLANDS. INVESTIGATION OF THE CENTRAL ARCTIC REGIONS

The Arctic Ocean is a vast field in which Russian glory can be enhanced.

M. V. Lomonosov

When we compare the maps found in the world atlas published in Russia in 1916 [9], which reflect all the exploratory work accomplished in the Arctic in the pre-revolutionary period, with today's map of the Soviet Union, we will notice immediately some marked differences, especially in the Soviet sector of the Arctic, the most striking changes being in the Kara Sea—Severnaya Zemlya region. It was here that many important discoveries were made over the years of Soviet power.

On the 1916 maps, Severnaya Zemlya is shown as two big islands with the shoreline traced only on the eastern and southern sides, and not completely and only approximately. The western side of the islands and northern areas were then completely unknown.

After Severnaya Zemlya was discovered in 1913 by the Russian Arctic Ocean Hydrographic Expedition, which that year made an approximate mapping of its eastern and, in 1914, of its southern configuration, this arctic land was not revisited until 1930. The arrangement and features of the islands comprising Severnaya Zemlya were ultimately determined by an expedition from the Arctic Institute in 1930-1932.

The 1930 expedition to Severnaya Zemlya discovered the ice-covered Island of Schmidt* and several smaller islands including Dlinny Island and the islands of the Sedov Archipelago, named after the icebreaker, *Georgi Sedov*, used on the expedition.

A party of four, headed by G. A. Ushakov disembarked at one of the islands (Domashny Island in the Sedov Archipelago) to establish the expedition's main base. It consisted of a house, a wind turbine, a short-wave radio station and enough supplies of various kinds to last three years. The party had sledges and 43 dogs for transportation.

As the explorers were later to learn, the island on which they established their base was only a few score kilometres from the large islands of Severnaya Zemlya—Pioner and Oktyabrskaya Revolutsia islands.

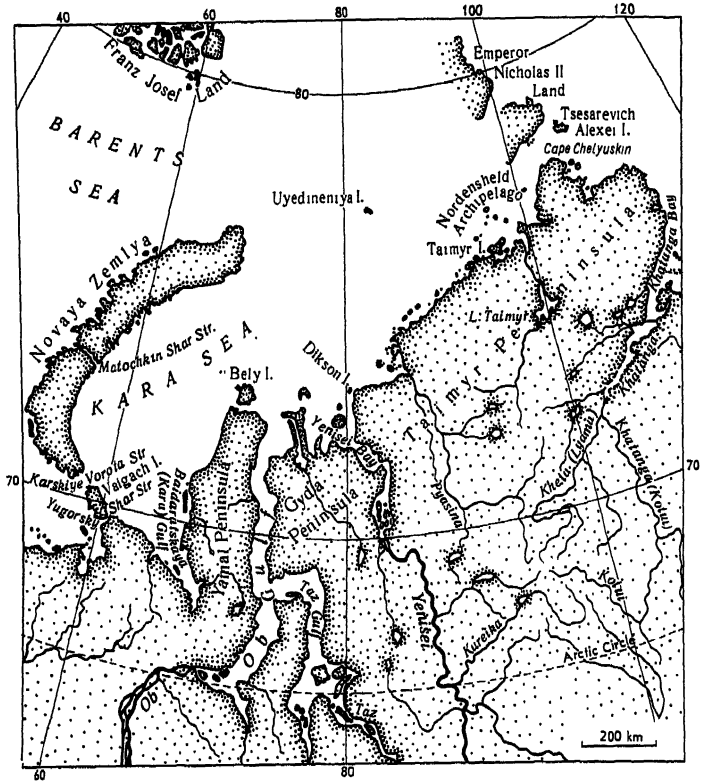
The base island was small and of low elevation. "It had no hills, no mountains, no rivers, and no lakes—there wasn't enough room for them here anyway. This was simply the crest of a limestone fold jutting out of the sea. It rose in a narrow, humped strip, resembling a whale's back showing above the water. When we first stepped onto its slippery ice-covered surface we involuntarily trod very carefully, as if we really were walking on a whale who was ready at any moment to submerge into the icy deep" [10].

The absence of mountains, or, for that matter, any noticeable rises whatever, made the surrounding landscape particularly monotonous, bleak and dismal. "I have seen God-forsaken Chukotka Peninsula, blizzard-ridden Wrangel Island, twice visited fog enshrouded Novaya Zemlya, and I have seen Franz Josef Land with its enamel sky and proud cliffs garbed in blue, hardened glacial streams, but nowhere did I witness such grimness or such depressing, lifeless relief as on our little island," wrote Ushakov.

But little by little, the people became accustomed to their new home, and when they returned to it from their long and arduous sledge trips, they found it peaceful, restful and even cozy.

The leader of the expeditionary party, Ushakov, carried with him a document which read as follows: "The bearer, Deputy Director of the Arctic Institute Georgi Alexeyevich

* The Island of Schmidt was discovered after the party, under G. A. Ushakov, disembarked.



The Kara Sea and the northern coast of Siberia as shown on the 1916 map

Ushakov, is dispatched to Severnaya Zemlya as head of the Northern Expeditionary Party of the government's Arctic Expedition. Comrade Ushakov and his party are charged with the exploration of Severnaya Zemlya. In the event ships fail to reach Severnaya Zemlya in the next two navigations or owing to any other conditions developing during the period of work in Severnaya Zemlya, Comrade Ushakov and his party should cross Vilkitski Strait and pass by dog sled through Taimyr Peninsula to settled areas, from where he should proceed to Leningrad" [11].

Such was the challenge facing the party of intrepid arctic explorers that landed on Domashny Island—to find and explore Severnaya Zemlya and if necessary to get back to civilisation on their own! But first they had to chart the as yet unknown seacoast of Severnaya Zemlya and to deter-

The Kara Sea and the northern coast of Siberia as shown on present maps

mine its extent to the north and west. They had to find out whether this was one huge island that would, as many then thought, obstruct navigation over the Northern Sea Route, or several islands with straits perhaps wide enough to allow ships to pass through them. They had to study the geological structure of Severnaya Zemlya, investigate its flora and fauna, its climate and the ice conditions of the sea around it. This exploration of Severnaya Zemlya was more than of purely scientific interest; it was also of great practical importance for the contemplated development of the Northern Sea Route.

A month after the *Sedov* landed the explorers on Domashny Island, the party set out with two dog-driven sledges on a reconnaissance trip to the mainland of Severnaya Zemlya. Only the radio operator stayed behind at the base.

After a three-day sledge trip covering 69 kilometres, they reached a cape on the western shore of Severnaya Zemlya, where at noon on October 5, 1930, they raised the red flag of the Soviet Union. In honour of the emblem embroidered on the flag, they named the cape Mys Serpa i Molota (Hammer and Sickle).

As they proceeded along the coast they plotted the contour of the shoreline on a map. New names appeared on the map. We find the following entry under the date of October 7, 1930, in Ushakov's diary: "We covered 25.9 kilometres. We made camp near a high limestone promontory. Yesterday there was a blank space on the map at this point, but from today on a cape will be marked there. It is called Oktyabrsky." And further on, he wrote: "In the morning we finished surveying Sovetskaya Bay. It extends inland for a distance of about 10 kilometres..." [12]. Thus, the explorers began to fill in a big blank space on the map. During that October reconnaissance trip, 145 kilometres of the coastline were surveyed.

Some difficult sledge trips over the large islands of Severnaya Zemlya were made during that long and severe winter to leave caches of provisions at various distant points, some very remote from the main base.

In the spring and summer of 1931, relying on these caches as it proceeded, the expedition traversed the entire northern part of Severnaya Zemlya and reached Cape Arktichesky.

Before setting out for the northern extremity of the islands, the party explored and surveyed the eastern shore in an area that had already been mapped by the hydrographic expedition made on the *Taimyr* and *Vaigach*. Some big corrections had to be made in that map, which gave no hint, for example, of the existence of a strait that was later to be named Red Army Strait. Errors on the old map were to be expected, since the survey had been made from aboard a ship.

But making corrections on what was already entered on the map was only a minor part of the new expedition's work. Basically its task consisted in exploring and mapping hitherto unknown and uncharted areas.

On the east coast, the explorers took astronomical observations and coordinated their survey with the astronomical point* on the Cape of Berg on Oktyabrskaya Revolutsia

* An astronomical point is a point whose geographical coordinates—latitude and longitude—are determined with a certain degree

G. A. Ushakov and Professor O. Y. Schmidt discussing plans for the expedition to Severnaya Zemlya

Island, and made geological investigations. Then they headed north along the eastern coastline of the islands.

"...On May 8, we broke camp and headed north into the unknown," wrote Ushakov in his diary. "The going was extremely difficult. The edge of the huge ice sheet covering the northern island (Komsomolets) turned westward. Beyond it stretched a low lying coastline, sloping down so low that it was hard to know whether you were on the shore or on the ice."

The 16th of May was a gala day for the expedition: it had reached the northernmost part of the Severnaya Zemlya islands (Cape Arktichesky).

The area around the new camp was a small glacial sheet, the highest point of which was a little to the south. The glacier sloped towards the sea, and only at one place did it form, for a short distance, a sheer precipice. By it, the open sea lapped quietly and calmly.

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of accuracy by astronomical observation. These observations fix the location of base points used in topographical surveying at the initial stages of studying a particular territory.

The waters of two seas met here—the Kara and Laptev seas, while to the north stretched the central basin of the Arctic Ocean. The explorers stood on the northernmost land point in this sector of the Arctic.

They quit Cape Arktichesky on May 19, carrying away with them their original impression of it—white, bleak and severe.

In June they crossed the central island (Oktyabrskaya Revolutsia Island) and came out again onto the eastern coast to Cape Berg. On the way they examined traces of ancient glaciation in a fjord—evidence of glacial recession.

From Cape Berg, the men went south towards Cape Anuchin, entering corrections on the 1913 map as they went along. At Anuchin they took astronomical observations. "We did this because of some large discrepancies between the actual outline of the coast and the map. Besides the bay that was missing from the map we discovered two small islands a little north of the cape. We think that they must have blocked the [1913] expedition's view of the bay from the sea" [13].

Thus, what was shown on the map of the 1913 hydrographic expedition as Cape Arnhold turned out to be an island that had apparently misled the seamen who took it for an extension of land jutting out into the water. "We closed down Cape Arnhold and opened up an island, giving it the same name," Ushakov wrote in his diary.

It was a heart-warming event when the party spotted some geese, whose arrival augmented the list of birds found on these islands that had at first seemed so lifeless. "We even felt a sort of gratification," wrote Ushakov, "a feeling of pride for Severnaya Zemlya. We have already come to love it and endearingly call it 'ours'. Every new cranny, cape, hill or glacier that finds its way onto the world map as a result of our efforts makes us that much more attached to it."

The travellers set out to investigate the inner reaches of Shokalsky Bay, shown on the 1913 map. Far ahead of them, but now seeming to come closer and closer as they moved towards it, was a cape. "Its brown rocky mass loomed larger and larger from behind a sparkling glacier."

Finally, the travellers passed the last cascades of the glacier and came up to the cape itself. The shore along which they were walking turned to the south-west, while the opposite shore continued on southward as before. The wide space

between the shores was filled with ice hummocks. It became clear that the travellers were not in a bay, but in a strait at its narrowest point.

This was yet another big discovery. From that moment, Shokalsky Bay disappeared from the map, to be replaced by Shokalsky Strait—a new gateway between the western and eastern parts of the Soviet Arctic.

The explorers proceeded west over the ice-packed strait and rounded the southern tip of Oktyabrskaya Revolutsia Island. On the last leg of that trek they ran into exceptionally difficult conditions. Whereas before, they had had to cope with darkness, snowstorms, fog and cold, now it was the melting snow and water that gave them the biggest trouble.

In the second half of June, the temperature had risen to +5°C and the snow had become slushy. It was painfully hard going both for the men and for the dogs. With strenuous effort, they covered only five kilometres a day and even considered that much to be an accomplishment. Men and dogs sank deep into the snow. Even skis were useless, and soon the snow on the ground was almost completely melted. It became impossible to walk any further along the shore itself; impassable ice hummocks in the sea and deep lakes on the ice ruled out those two alternatives. The only pos sibility was to move ahead along a narrow strip of submerged ice adjacent to the shore, but this too presented great difficulties.

"The surface of the ice along the shoreline began to look like a gigantic grater because of the thawed ice crystals..." wrote geologist N. N. Urvantsev, a member of that expedition and the one who did most of the surveying and cartographic work. "The dogs soon suffered torn and bloody paws on that terrible road, and some wore their paws down to the tendons and even to the bone. And it was no easy going for the men either. At times, they would be up to the waist in the icy water, straining to the utmost and helping and encouraging the exhausted dogs. The dogs were so worn out that as soon as we unharnessed them, they simply collapsed on the spot and no power on earth could have made them budge" [14]. The dogs were dying of exhaustion. The men, having given the dogs all that was left of the butter and chocolate and themselves eating only rice, barely made it back to the base.

N. N. Urvantsev

In the spring and summer of the next year, the party explored and mapped the big southern Bolshevik Island, and Pioner Island, which lay closest to the base.

Bolshevik's southern shore, washed by the waters of Vilkitsky Strait, and its eastern shores, facing the Sea of Laptev, had been examined and mapped from aboard the *Taimyr* and *Vaigach* during the hydrographic expedition of 1913-1914. Ushakov's task was to check the survey of the shoreline. But the explorers already knew from past experience that this really meant making a new survey.

And that is what actually did happen. When plotted on the hydrographers' old map, the coordinates of the island's northern tip, as determined by Ushakov's expedition, lay in the water far from what was shown there as the shoreline. From aboard their ship, the seamen had apparently mistaken the long, low terrace-like northern extremity of the island for fast ice. Consequently, their map showed only the high cliffs further inland, so that the northern part of the island was cut short by more than 32 kilometres. Moreover, the shore facing Shokalsky Strait and the Kara Sea had not been charted at all.

On May 22, 1932, the expedition had completed its circle of Bolshevik Island. The last trip to Pioner Island was completed in early June. It had lasted only eight days.

"On the evening of June 8," wrote Ushakov, "we were already home. And on June 9, a heavy storm blew in from the south-west. It started to warm up a bit. At first it snowed heavily, and then it began to rain. Everything was turning to slush. Summer had arrived.

"But we were indifferent now as far as the weather and the travelling and ice conditions were concerned. Our field work was done. Severnaya Zemlya was now completely surveyed. Our job of making the initial exploration of it was finished. Our report that the work of the expedition had been completed went to Moscow by radio..." [15].

In the course of that expedition, Ushakov's and Urvantsev's party had covered no less than 5,000 kilometres by dog sled. Of these, about 2,220 kilometres were traversed while doing topographical work.

Thus, as a result of two years of selfless effort by the Soviet arctic explorers, a huge blank space was removed from the map and 37,000 sq km of land in the midst of the arctic seas was placed on the map.

Courageous men wrested new secrets from the Arctic and discovered new islands, straits, bays, capes, mountains and glaciers. Severnaya Zemlya in its entirety was now clearly and precisely represented on the map of the Soviet Union.

It had now been determined that Severnaya Zemlya consisted of five large islands and a number of smaller ones scattered either in groups or by themselves. The inland areas of the big islands are covered with dome-shaped glaciers, which reach especially large proportions on Komsomolets Island, where 65 per cent of the land surface is covered with ice.

Ushakov's expedition studied the relief and geological structure of the islands, their climatic conditions, their flora and fauna, and the ice conditions in the seas surrounding Severnaya Zemlya.

The first map of Severnaya Zemlya reflecting the results of Ushakov's expedition was published in the newspaper *Izvestia* on October 16, 1932. It was the world's first accurate picture of the extent and configuration of the tracts of land lying beyond Cape Chelyuskin, the northernmost point in Asia.

Two expeditions in 1932 made certain additions to the map of Severnaya Zemlya. One, carried out on the *Rusanov*, investigated Shokalsky Strait, while the other, on the *Taimyr*, surveyed and sounded Kalinin Bay on Pioner Island and also explored Shokalsky Strait, at whose southern entrance eight small islands—the Krasnoflotskiye Islands—were discovered.

In 1936, exploration of Shokalsky Strait continued, and between 1940 and 1942, a detailed investigation was made of Cape Arktichesky, the Krasnoflotskiye Islands and the southwestern shoreline of Oktyabrskaya Revolutsia Island. In 1945, a small island north of Schmidt Island was discovered by aircraft.

Subsequent explorations, in which aircraft and new methods of land study were used, brought substantial corrections to the map of Severnaya Zemlya that had been drawn up by the intrepid explorers in 1930-1932. Nonetheless, the new explorations showed that the surveys that Ushakov's party had made, as we have seen, under incredibly difficult conditions, were reasonably accurate.

The large islands of Severnaya Zemlya have many lakes and rivers. Some rivers—those that are fed by glacial melt-water—are permanent, while others lose their water and virtually disappear after the snow has melted. Summer lasts about two months, during which time tundra vegetation appears, but there is almost no dense ground cover anywhere. Huge icebergs up to three kilometres in length now and then break away from the ends of the glaciers creeping down into the sea, thus causing substantial alternations in the shoreline.

* * *

If we compare the representation of the Kara Sea on the 1916 map with its representation on today's map, we can easily spot the large number of islands that have been discovered by Soviet arctic expeditions—the islands of Ushakov, Vize, Voronin, Sergei Kirov, Izvestia TsIK, and Arctic Institute, to name a few.

The story of how the island of Vize was discovered is quite interesting. Its location was predicted by eminent Soviet arctic explorer, V. Y. Vize, on the basis of his study of the drift course taken by the *St. Anna* (1912-1914), the vessel carrying an expedition under Lieutenant G. L. Brusilov—an expedition which, incidentally, had ended disastrously. By carefully tracing all the zig-zags made by the *St. Anna* and checking them against the direction of the wind, Vize determined that between latitudes 78°N and 80°N there must have been some obstacle preventing the ship from proceeding eastward. He concluded that the obstacle must have been a piece of land, and he calculated

its approximate location and even plotted it on a map that was published in 1924.

In 1930, the land that had been theoretically discovered six years earlier "on paper", was actually found by an expedition—in which Vize himself took part—sailing on the icebreaker *Georgi Sedov*. The land was named the Island of Vize. Lost in the icy arctic expanses, this island presents a cheerless picture. It is low, composed of sedimentary rock and almost devoid of vegetation. Animal life on it is scarce, and even birds, usually plentiful on arctic islands in the summer, are rare.

V. Y. Vize

Vize was overjoyed when the island was discovered, and everyone on board the *Georgi Sedov* was glad for him. But after landing and examining the island, Vize was heard to say: "What a wretched place this is!"

That little island could not possibly have affected the drift course of the *St. Anna* to the extent that Vize had reckoned. There must have been some other obstacle nearby. Subsequent explorations in the northern part of the Kara Sea established that there was an enormous shoal lying a little to the east and running north-south at approximately 80°E. The northern part of this shoal and the ice-capped Island of Ushakov situated on it were discovered in 1935 by a high latitude expedition on the icebreaker *Sadko*. The expedition was headed by G. A. Ushakov, with N. N. Zubov in charge of the scientific work.

In planning the expedition, the organisers decided to take advantage of the favourable ice conditions that were expected in the summer of 1935 in the western sector of the Arctic. After carrying out an extensive programme of work

in the Greenland and Norwegian seas, the *Sadko* expedition rounded Spitsbergen from the west to make detailed explorations of the northern part of the Kara Sea. It "discovered here the central meridianally situated Sadko Shoal with the Island of Ushakov located on it, and several small islands off the western shores of Severnaya Zemlya, and penetrated the northern part of the Kara Sea, without encountering any ice problems whatever, as far as latitude 82°41.6′ and longitude 87°04′" [16].

The Sadko Shoal is part of an underwater rise (the Central Kara Rise), on the western edge of which rises the Island of Vize and on the southern part of which is located Uedineniya Island.

* * *

The outline of the eastern coast of Novaya Zemlya had to be redrawn on the map after a hydrographic expedition on the *Taimyr* in 1921 surveyed the coast from the northern tip of Novaya Zemlya—Cape Zhelaniya—to Blagopoluchiya Bay, the then newly discovered fjord running deep inland. Prior to the 1921 expedition, this sector of the shore had been charted very roughly, primarily on the basis of data provided by Norwegian merchants and fur traders. Valuable geographic information was obtained by an expedition (1923-1924) of the Chief Hydrographical Administration, in which A. I. Tolmachev took part, to the Matochkin Shar region and the east coast of Novaya Zemlya. In 1925, an expedition of the Institute of Northern Studies circumnavigated Novaya Zemlya on the motor-boat *Elding*, and discovered three bays—thereafter known as Rusanov Bay, Neupokoyev Bay and the Bay of Sedov—on the east coast of the northern island.

The map of Novaya Zemlya's northern island today shows heights of over 1,000 metres above sea level (Sedov Peak near Matochkin Shar Strait, Mt. Blednaya in the Mendeleyev Mountains, and others), which the old maps did not indicate. The greatest height is over 1.5 kilometres (1,590 m). The ice sheet on this island stands out clearly.

Substantial corrections of earlier maps were made as a result of explorations of Vaigach Island and Kolguyev Island by A. I. Tolmachev (1921-1925), I. A. Perfilyev (1927-1928) and others.

Some drastic changes have also been made in the map of Franz Josef Land. Some islands have been more accurately outlined, while others have been put on the map for the first time. About a score of islands have been added to the map of this arctic archipelago as a result of new exploration. It was determined that 87 per cent of the islands' surface is covered by an ice sheet.

* * *

The eastern seas of the Soviet sector of the Arctic did not yield such important discoveries as did the Kara Sea, but the contours of some previously known islands were markedly altered. Wrangel Island, for example, became "rounder", and today's map shows Mt. Sovetskaya (1,096 m) and not Mt. Berri (760 m)* as the island's highest point. Exploration of Wrangel Island by Soviet experts began in 1924, when the gunboat *Krasny Oktyabr*, carrying an expedition under hydrographer and geodesist B. V. Davydov, sailed there to take astronomical and magnetic observations. Ushakov worked there in 1926-1929, making a topographical survey of the coastline and drawing up the first more or less accurate map of the island. Later work included a survey of the entire island and the drawing of a more detailed and accurate map (1941); study of the flora (by B. N. Gorodkov); soil and relief studies; the discovery of glaciers in the mountains, and the study there of traces of ancient glaciation.

New information about the eastern part of the Soviet sector of the Arctic gave a more precise picture of the configuration of the New Siberian Islands, as for example Novaya Sibir Island. Faddei Island turned out to be a peninsula connected by an isthmus to Kotelny Island.

* * *

The cartographic representation of the bottom relief of the central parts of the Arctic Ocean and the seas around it was also changed substantially. In fact, nothing at all had previously been known about the ocean depths in the polar region.

The 1930 expedition on the icebreaker *Georgi Sedov* took many soundings and provided the first measured picture

* The height of Mt. Berri is now considered to be 964 m.

of the floor in the northern part of the Kara Sea. The 1935 *Sadko* expedition discovered the shoal in the area around Ushakov Island. "A whole new sea" was discovered by Soviet expeditions working north-east of Novaya Zemlya, "for prior to these expeditions a huge part of the water expanse between the northern tip of Novaya Zemlya, Franz Josef Land and Severnaya Zemlya had never been visited" [17].

Soviet explorers also measured the depth and width of the continental shelf in the eastern seas of the Soviet sector of the Arctic.

The first measurements of the ocean depths at the very "top" of the Soviet sector of the Arctic, that is, at the pole, were taken by a courageous four-man team of Soviet polar explorers working on the drifting station North Pole 1.*

On May, 21, 1937, the first airborne high latitude expedition, headed by O. Y. Schmidt, landed at the North Pole, thus accomplishing the world's first airplane landing at one of the Earth's poles (almost two decades later, in late October 1956, an American airplane landed at the South Pole).

The purpose of the flight was to land a four-man party under I. D. Papanin (now Chairman of the Moscow branch of the Geographical Society of the USSR) to set up a scientific station on the drifting ice at the pole. Once the party and its equipment were landed, the plane carrying the head of the expedition, Schmidt, returned home. Papanin's party, which included hydrologist P. P. Shirshov, geophysicist E. K. Fedorov and radio operator E. T. Krenkel, began their extensive programme of scientific work.

The ice field on which North Pole 1 was set up began to drift, at first heading south, then moving in a south-westernly direction, carrying it from the central part of the Arctic Ocean into the Greenland Sea. In February 1938, the men were taken off the ice floe not far from Greenland, a little south of latitude 71°N. A hearty reception awaited them in Moscow.

The depth of the ocean at the pole (at latitude 88°54'N and longitude 21°W) was found to be 4,290 m. Measurements taken by Shirshov and his co-workers showed that the

* Robert E. Peary, the first man to reach the North Pole (1909), tried to measure the depth of the Arctic Ocean. Taking advantage of a crack in the ice five miles from the pole, he lowered a wire with a sinker. But the 2,752 m of wire reeled out did not reach bottom.

Papanin's polar team. Left to right: P. P. Shirshov, E. T. Krenkel, I. D. Papanin, E. K. Fedorov

entire area between the pole and latitude 86° is a deep basin with a sloping bottom and a maximum depth of 4,395 m.

Here are a few entries in Papanin's diary about some of the first measurements taken between June 6 and July 17, 1937.

"In the evening, Petrovich (P. P. Shirshov—*N.G.*) lowered line and sinker to measure the depth of the ocean. The depth is four thousand two hundred ninety metres. He took a sample of the bottom; it turned out to be greenish grey fine silt."

"...Shirshov worked at the hole with the winch, and I helped him. At midnight, he will start making a 24-hour station, this means that he will be at the winch day and night around the clock."

"Got the winch ready. We have a hard job ahead of us today—to measure the depth of the ocean.

"At 12 hours 30 minutes our sounding lead hit bottom. The depth is four thousand three hundred and seventy four metres—eighty four metres more than at the first sounding. So, just as Pyotr Petrovich reckoned, it gets very deep in the centre of the polar basin, so there being any land close by, as some scientists had expected, is out of the question.

"We had to let out four kilometres of line on the winch to measure the depth.

"Our coordinates today: 88°47'N and 10°W.

"It took us five hours to pull the sounding lead back up to the surface...."

"Helped Pyotr Petrovich to set up a hydrological station at a depth of four thousand metres. This took all day. I was so exhausted that I couldn't even make my entries in the diary. Went to bed and slept like a log...."

"It's hard and exhausting work to pull the weight up from a depth of four thousand metres. This additional physical stress is very perceptible. But the schedule of scientific work mustn't be changed...."

"The sounding showed a depth of four thousand three hundred and ninety five metres. Thus, the ocean bottom along the line of our drift so far continues to go down. Began to crank the windlass. We all worked for four hours without a break. The wind was blowing and it was cold and damp, but at times we got so overheated from the work we had to shed our clothing" [18].

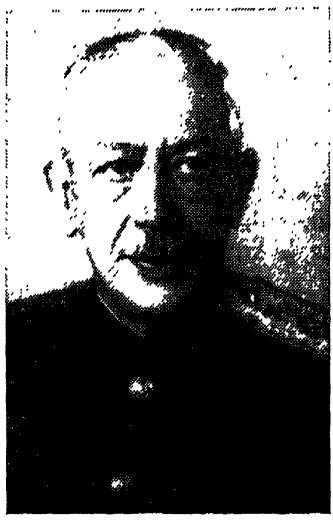
As we can see, the men were not on a pleasure cruise.

Prior to the landing of Papanin's party, the North Pole had been visited four times, but during those earlier visits no really important scientific observations were taken, so that actually the vast central part of the arctic basin still remained a blank space.

The party manning the drifting station North Pole 1, however, conducted a series of important observations. They took 33 soundings to determine the depth of the ocean floor;

they set up hydrological stations 38 times, where they measured the temperature of the water and, using special instruments called bathometers, took water samples from various depths ranging from the surface to the ocean floor; and they set up hydrobiological stations 22 times, gathering organisms inhabiting various depths of the ocean.

They also took many astronomical observations to determine their exact location during the drift, otherwise their other observations would have lost their value.



N. N. Zubov

Using special instruments they studied the ocean currents under the ice and checked the velocity and course of the ice field's drift. They took periodical gravimetric (measuring the force of gravity), magnetic and meteorological observations and studied the atmospheric electricity and the polar lights.

Although the North Pole 1 station drifted outside the Soviet sector of the Arctic, the scientific observations shed light on the natural features of the central part of the arctic basin in general and were very important for the further study and development of the Soviet arctic expanses.

The North Pole 1 observations revealed that warm Atlantic waters flow in a deep current from the Greenland Sea to the very pole and that the temperature of the water rises in the deepest part of the arctic basin due to the internal heat of the Earth. Various forms of sea life were found in the polar region, completely refuting earlier notions that the central part of the arctic basin was, to use Nansen's words, a completely lifeless "ocean desert". And the meteorological observations disproved earlier theories regarding the structure and circulation of the atmosphere in the high arctic latitudes.

Of tremendous practical and theoretical significance were the observations of the drift itself and the behaviour of the ice fields in the Central Arctic. Eminent arctic explorer Professor N. N. Zubov notes the following on this score: "The very fact that the polar station did not remain in the upper latitudes for about a year, as had been expected, but ended up below latitude 71° in a matter of nine months, shows how wrong our conception of the movement of drift ice in the Central Arctic Basin had been" [19].

In this respect, the drift of the icebreaker *Georgi Sedov* also provided important data.

The *Georgi Sedov*, a ship of the merchant fleet, was not built to withstand powerful ice compression. Moreover, there were no specialists among its crew except for V. H. Buinitsky, then a student at the Hydrographical Institute (now a professor at Leningrad University). During the forced drift, all 15 members of the crew became involved to one extent or another in taking scientific observations.

The drift began in October 1937, after the ship was caught in the ice near the New Siberian Islands, and ended 812 days later, in January 1940, when the *Georgi Sedov* was freed from its icy prison by a Soviet icebreaker-flagship in the strait between Spitsbergen and Greenland.

The drift conditions were exceedingly complicated and dangerous. The heavy ice would break up into huge hummocks around the ship, threatening to crush it. The crew had to work feverishly with dynamite and fuses to blow up the most dangerous hummocks. Emergency supplies had to be made ready for unloading onto the ice. Meanwhile, the hull groaned and creaked in the powerful embraces of the ice mass around it. Nonetheless, the crew carried out systematic observations—meteorological, hydrological, magnetic, gravimetric and astronomical. They measured the thickness of the ice and observed the polar lights.

Their observations were especially valuable because the *Georgi Sedov* drifted for over two years, almost three times longer than the station North Pole 1 and more than twice as long as Fridtjof Nansen's ship, the *Fram*.

The deepest sounding made during the *Sedov*'s drift in the western part of the Soviet sector of the Arctic was 5,220 m, at a point where the sounding lead did not even reach bottom. Subsequently, the US research submarine *Skat*

measured a depth of 5,335 m in what is now known as the Georgi Sedov Trough.

The 5,440-metre sounding taken in 1927 in the eastern part of the Soviet Arctic by polar explorer George Hubert Wilkins turned out to be erroneous, although it was shown on all geographical maps for many years.

In the fall of 1939, N. N. Zubov and two famous flyers, pilot I. I. Cherevichny and navigator V. I. Akkuratov, worked out a plan for an expedition to the so-called Pole of Relative Inaccessibility area.* Cherevichny's USSR-N-169 aircraft flew from Moscow to Wrangel Island, from where in April 1941 it made three flights to the north, landing on the ice at points with approximately the following coordinates: 1) 81°32′N and 180°E; 2) 78°26′N and 177°20′E; 3) 79°54′N and 190°05′E. The landing points thus formed a triangle near the place where Wilkins's sounding of 5,440 m was taken. The soundings taken at the three points showed depths ranging between 1,850 and 3,400 m. "...The soundings showed," wrote Zubov, "that the 5,440-metre reading taken by Wilkins at latitude 77°46′ and longitude 185° was apparently erroneous" [20]. Zubov's conclusion was verified by subsequent soundings in that area.

The Pole of Relative Inaccessibility is the name given to the point in the Arctic, most distant from those land areas on which it is relatively easy, with the help of ships capable of sailing through the ice, to set up an intermediate base for air routes. The point is located at about 83°40′N and 190°E (170°W) and is approximately equidistant from the northern outskirts of the New Siberian Islands, Wrangel Island, Alaska and the islands of the North American Archipelago.

CHAPTER 3

NEW EXPLORATIONS IN THE CENTRAL ARCTIC. DISCOVERY OF LOMONOSOV RIDGE AND OTHER RIDGES AND RISES ON THE FLOOR OF THE ARCTIC OCEAN

...It is to the ordinary, day-to-day work of the polar teams that we are indebted for the basic mass of information about the Arctic.

N. N. Zubov

Many secrets of the polar region of the Soviet sector of the Arctic relating to the central part of the Arctic Ocean or to the Central Arctic were revealed by Soviet polar explorers in the post-war years.

The development of the Northern Sea Route required a thorough study of the Central Arctic, for the ice and climatic conditions in the polar regions affect the ice and climatic conditions along the northern coast of Siberia upon which the possibilities of navigation depend.

In the previous chapter, we discussed some of the work done in the central parts of the Arctic Ocean prior to the Great Patriotic War (the North Pole 1 station and the air expedition to the Pole of Relative Inaccessibility area). Those expeditions, however, were only the beginning. Further development of the Northern Sea Route, aimed at making a major waterway not only for serving the regions of the Far North but also for transit shipping, required more extensive and systematic exploration and study of the Central Arctic. This was also essential for weather forecasting purposes.

The basic methods of investigation had already been found and tested before the war. These included stationary observations on drifting ice fields (North Pole 1 station), or on board a ship (*Georgi Sedov*) and the use of aircraft to land at predetermined points, where brief but comprehensive

scientific observations are taken. The latter method, tested by the air expedition to the Pole of Relative Inaccessibility area, has been dubbed the "flying laboratory" method.

An extensive programme of Central Arctic exploration had been worked out prior to the Great Patriotic War, but was held up because of the war. Nevertheless, exploration was not halted altogether during the war years. Flyers in the polar aviation servicing navigation over the Northern Sea Route flew frequent ice patrols in the upper latitudes, checking on ice and weather conditions in the central part of the Arctic Ocean.

In 1945, flyer M. A. Titlov flew to the North Pole with a team of scientists, who made observations of the ice cap and brought back valuable data.

In 1946, during a routine ice patrol, flyer I. S. Kotov spotted a large, hilly "island" about 400 to 500 sq km in area, rising above the drift ice north-east of Wrangel Island. The following year, the same "island" was sighted some 200 miles further west. It was learned that there are huge islands of ice floating in the Arctic Ocean. A fragment of such an island was examined from an icebreaker in the summer of 1947. Scientists established the fact that the ice island was of continental origin.

In 1948, flyer I. P. Mazuruk discovered a huge ice island at 85°40′N and 140°50′E. A short time later, other flyers spotted that same island—7 to 8 m high, 32 km long and 28 km wide, with a wavy surface similar to that of a glacier—very near the pole.

A third large island was spotted in 1950 by V. M. Perov, a flyer in the polar aviation service. His island was not far from the place where Kotov discovered the first floating island in 1946.

These drifting ice islands are huge blocks of continental ice apparently originating from the shelf of Greenland and the islands of the Canadian Archipelago, particularly Ellesmere Island where there is the so-called shelf ice that had recently covered large areas. Only remnants of it are found today, the greater part of it having broken off and drifted away into the Arctic Ocean.

The drifting ice islands were kept under observation in the following years, revealing important features of the ice drift in the central part of the Arctic Ocean.

The discovery of large ice islands was also important from the standpoint of general geography. It solved once and for all the question of legendary lands that had so long been a puzzle to scientists. Data on the drift of the ice islands and on the characteristics of the islands themselves indicate that "the polar explorers who saw pieces of land actually saw nothing other than drifting ice islands. Those explorers were, in fact, the first to discover the gigantic icebergs that roam the Arctic Ocean" [21].

Early explorers may also have erroneously thought they were seeing large tracts of land when they saw big piles of hummocked ice, strongly elevated by refraction*, or when they came across dense fog hanging over the open expanse of water, which under certain illumination can give the impression of an island or land.

In any event, arctic exploration has resulted not only in the discovery of hitherto unknown tracts of land, but also in the removal from the map of many mythical lands that had appeared on maps for a long time, such as Sannikov Land, Andreyev Land, Makarov Land, Gillis Land, Peterman Land, etc.

The year 1948 marked the beginning of a broad, systematic study of the Central Arctic, especially in the region north of the New Siberian Islands. The work involved many flyers and aircraft from the polar aviation service and teams of scientists who were not only experts in their fields, but men of unusual courage, daring and persistence.

The exploration and research was integrated, meaning that specialists in various fields—oceanologists, geophysicists, meteorologists, aerologists, hydrobiologists, etc.—worked together in detachments or teams.

Such teams were flown thousands of kilometres from the mainland to the most distant parts of the Arctic Ocean, where they were landed with their specially-built modern portable equipment. The simultaneous observations of several groups in different areas gave an overall picture of the meteorological and geophysical processes, the general features of ice field drift, etc. There was, however, a substantial shortcoming in the 1948-1949 programme: the airborne teams worked only in the spring and summer. The

* Refraction—the bending of light rays in the atmosphere due to a decrease of density with height and a consequent reduction in the index of air refraction.

year-round picture of the development of meteorological and hydrological processes was therefore still unclear.

To fill in this gap, a scientific research station, headed by M. M. Somov, was set up in the spring of 1950 to take year-round observations. This was North Pole 2, history's second drifting scientific station in the Central Arctic.

The station was flown out and landed on the ice in the least studied part of the Arctic Ocean—at 76°02′ N and 166°30′W in the Pole of Relative Inaccessibility area. The station was taken off the ice 376 days later at 81°45′N and 162°20′W.

The station carried out a comprehensive research programme, including oceanographic, aerometeorological and geophysical observations. The results made a substantial contribution to our knowledge of the natural conditions in the vicinity of the Pole of Relative Inaccessibility.

In accordance with a government decision, a large high latitude arctic expedition was organised in 1954. It was considerably larger than previous arctic expeditions both in the number of people taking part in it and in the amount of research accomplished. In charge of the expedition's work was V. F. Burkhanov, who was then the head of the Chief Northern Sea Route Administration.

Taking part in the expedition were flyers who had only recently begun flying under arctic conditions, but there were also veteran flyers such as M. V. Vodopyanov, I. P. Mazuruk, A. D. Alexeyev and others, who in 1937 flew the North Pole 1 station to the North Pole. The team of scientists included veterans of many high latitude expeditions: M. E. Ostrekin, Y. Y. Gakkel, P. A. Gordiyenko, M. M. Somov and others. Working with them were many young researchers.

A direct part in the expedition's work was taken by scientists from the Academy of Sciences of the USSR, Moscow University and other scientific centres. Among them were academicians D. I. Shcherbakov, E. K. Fedorov (one of Papanin's four-man party) and L. A. Zenkevich; professors N. N. Zubov, A. D. Dobrovolsky, V. G. Kort, M. V. Klenova; and polar explorer V. V. Frolov, then the director of the Arctic Research Institute.

The expedition used various methods in its study of the Central Arctic, and above all the drifting station and "flying laboratory" methods. Improved flying techniques and devel-

opment of long-distance non-stop flights made it possible to send meteorological and ice patrols to the pole from various points on the mainland. Special mention should be made of the use of helicopters, which enabled polar drifting stations to expand the scope of their operations 100 to 150 kilometres beyond the immediate vicinity of their camps and to take scientific observations from various altitudes.

During the 1954 expedition, the Central Arctic was subjected to study from three directions at once. A detachment under the command of flyer I. I. Cherevichny, with M. E. Ostrekin in charge of the scientific work, flew from the mainland to the polar region through Franz Josef Land. Its task was to investigate the Arctic Ocean in the area between the pole and Greenland. A detachment under I. S. Kotov worked in the vicinity of the North Pole 3 station. And pilot M. A. Titlov headed a team working in the area of the North Pole 4 station.

The expedition was launched in April, when the mobile groups of Cherevichny's detachment set out on their exploration and study of a large area of the Arctic Ocean. All in all, they covered a strip on both sides of the pole that was 200 km wide and 1,000 km long.

The 1954 expedition marked the beginning of *permanent* scientific observations in the Arctic, since the stations landed on the drifting ice floes at that time became the bases for long-term observations.

The station North Pole 3, under A. F. Treshnikov, was landed at 86°00'N and 175°45'W, about 400 kilometres from the North Pole. It drifted towards the pole and passed it at a distance of only about 30 km.

The party did not notice anything unusual near the pole. "...Everything is plain and ordinary as before. The same ice as in other parts of the Central Arctic. Only the sun keeps going around the horizon 24 hours a day, never altering its height" [22]. By April 1955, the station had drifted in the direction of Greenland.

The drift of station North Pole 4 under E. I. Tolstikov began north of Wrangel Island, at 75°48'N, 178°25'W and, following a winding course, moved clockwise in an arc towards the more northern latitudes. By April 1955, it was north of latitude 80°N. In the course of a year, it had actually moved through a total distance of 2,600 km following

a highly irregular path, but when measured in a straight line, it had advanced only 530 km to the north. The ice floe not only shifted its direction from side to side but also rotated, making the meteorologist's job very perplexing, for it frequently seemed as if the wind had unexpectedly changed its course.

The North Pole 4 party chose a relatively high area for camp, setting up its tents and huts on hillocks to take advantage of the greater stability afforded by the greater thickness of ice underneath.

The personnel of both stations lived and worked in prefabricated houses and semi-spherical framed tents. The tent frames were made of lightweight duraluminum arches over which a black tarpaulin covering was stretched. The inside was lined with a layer of flannelette with a snow-white lining over it. The special rubberised floor was covered with deerskin and canvas. The tents were gas heated. This kind of tent, which can be assembled in 20 to 25 minutes, is roomy and comfortable and can withstand hurricane winds. But the prefabricated houses which have a floor space of 12.5 sq m are better for living and working in. They are assembled out of panels and are set up on skis, so that they can be moved over the ice (three men move a tent if that becomes necessary). Foam plastic is used for insulation; coal stoves are used for heat; collapsible furniture is used.

The men of both drifting stations went through a year of trying ordeals battling the severe arctic conditions.

From November 1954 on, the ice field on which North Pole 3 was set up was subjected to powerful pressure causing the ice to crack and break up into hummocks. Especially trying were the last weeks of December, when in addition to the strong ice motion, a severe blizzard came up and the temperature at times dropped to as low as —42°C.

Six times in the course of the year the ice field on which the station stood broke up. Sometimes the ice would break into such small pieces that it was impossible to stay on them any longer, so that the men would have to move the camp to another field, working in temperatures of up to —46°C. There were instances when the ice directly under the tents would crack, and fast action had to be taken. "And there were times when, in response to a signal from the man on duty, we would look out of our house or tent, and lighting our way with the weak beam of a flashlight sud-

Unloading supplies and equipment flown to the North Pole 5 station. Piled in the centre are arctic tent frames

denly find that we couldn't go any further: there in front of us, gleaming in the dark night, would be a black strip of water..." [23].

The commander of the station, A. F. Treshnikov, recalls in his diary that the calm and monotonous life on the ice floe during the first half of the drift was not to the liking of the motion picture cameraman who was with them. "What I need for my future picture are not only shots of day-to-day scientific work," he complained, "but shots showing the romance of the Arctic, the great hardships encountered here. Most people don't have any conception at all of how the ice right under the camp can break up into pieces."

The cameraman got everything he wanted on November 24, the very first time the ice field began to crack. He had to work hard to get that "romantic" episode on film. "And when on December 1 the field began to hummock again and the main crack passed right under the house in which the cameraman lived, he said that he already had his fill of romance and that he didn't need any more material for his future film..." [24].

North Pole 4 also experienced many partial break-ups of its ice field. The most dangerous time was in the summer of 1954, when the field became surrounded by an expanse of ice-free water. If the field were to break up, the pieces would quickly float away in all directions. During storms, the spray from the waves reached the camp. The edges of the field were breaking off. In the winter, the field was subjected to powerful compression. Great ridges of hummocks, piled up helter-skelter, grew up around the camp.

The powerful compression of the ice frequently made the landing strip unusable, so that the men would have to go out into the dark and freezing polar night to set up a new one.

Aviation played an outstanding role in the overall effort. Nearly 15 rail carloads of supplies and equipment were flown in to the camps of North Poles 3 and 4. In the summer of 1954, a total of more than one million kilometres were flown over the Central Arctic. Several hundred landings were made on the drifting ice fields, none of which, incidentally, was a forced landing.

Thanks to the courage and skill of the flight crews, the 1954 expedition was able to carry out a programme of unprecedented scope.

It is noteworthy that throughout the years, the many landings and evacuations of expeditionary teams were accomplished without a single accident. The landings were always made precisely at the intended points, which speaks highly of the skill of the navigators in the polar aviation service. However, the perfect accident record depended most of all on the courage and skill of the pilots who had to fly and land in extremely difficult and often dangerous conditions.

Especially difficult was one of Kotov's first flights to the North Pole 3 station, where in the middle of the polar night he had to deliver some special equipment that was needed

to make the landing strip there usable for subsequent night flights.

The weather between Franz Josef Land, where the flight began, and the North Pole 3 station was unfavourable for flying, but the flight could not be delayed or postponed. At first the plane flew through fog, then, breaking the clouds, it went up higher, continuing its blind flight. In a few hours it was near the station. Dense clouds hung over the ice field at a height of 50 metres. When the plane was over the station, it began to drop down, but entered the clouds and quickly began to be covered with ice. The icing was so great that even the plane's anti-icing device could not cope with it properly. It began to snow heavily and the plane began to lose speed. The front windows were now covered with ice, sharply reducing visibility. Still unable to free itself of the ice, the plane continued to lose altitude. It flew over the station at an altitude of 200 m, yet the murky spots of light over the landing strip could barely be seen through the thick fog. Covered with a layer of ice, the plane was losing speed and responding poorly to the controls. "Straining his eyes but orienting himself mainly by his instruments, Kotov decided, after the second approach, to risk landing, knowing that under those unusual circumstances it would be dangerous.

"Directly ahead of the plane as it was about to touch down was a wall of hummocks. A crash seemed inevitable. Red rockets flying into the air warned of the danger ahead. The pilot barely managed to nose the plane up into the air again to avoid the hummocks. He wanted to go up for another approach, but the plane would not respond to the controls. Barely missing the dangerous ridge of hummocks, Kotov decided to go for a landing on a strip of ice just beyond it. The aircraft dropped down heavily onto the ice, rolled for several tens of metres and stopped..." [25].

The teams of scientists working at North Pole 3 and North Pole 4 carried out a year-round programme of observations and gathered exceedingly valuable material. Over 10,000 routine meteorological observations were taken at each station. For the purpose of studying high atmospheric layers about 3,000 radiosondes and pilot-balloons were sent up, and over 2,000 observations of solar radiation were taken. The depth of the ocean was measured at more than 1,000 points. Prolonged deep water hydrological observations were

taken to determine the direction and velocity of ocean currents, to measure the temperature of the water and to study its chemical composition.

The polar scientists collected many samples of sea life and bottom sediment, studied the physical and chemical properties of the ice, and took systematic observations of the direction and velocity of the ice drift.

Scientific study and exploration of the Central Arctic continued systematically. It was decided that to get the most practical value from the aerometeorological information coming from the drifting stations, no less than two such stations should always be in operation simultaneously.

In the spring of 1955, the Chief Northern Sea Route Administration sent its next expedition to the Central Arctic. Its task was to keep the drifting scientific stations operating without interruption in 1955 and 1956.

The 1955 expedition effected an exchange of personnel at the North Pole 4 station, which continued its drift.

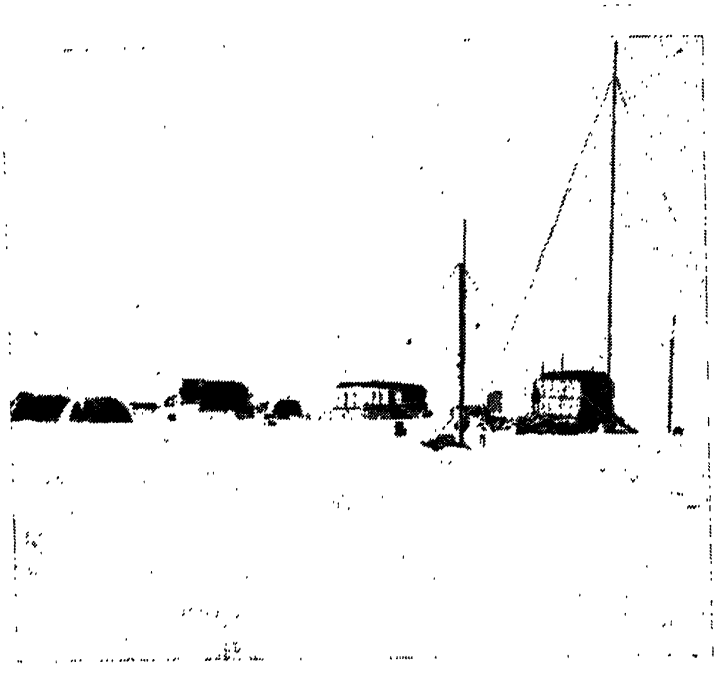
North Pole 3 was ultimately carried out to the periphery of the Arctic Ocean, whereupon it was decided to evacuate it. After traversing a long and complicated drift course through the central part of the Arctic Ocean, it was finally taken off the ice not far (less than 300 km) from Greenland. The head of the station, A. F. Treshnikov, wrote in his diary: "...We felt a kind of sadness in parting with our ice floe, for though it was cold and full of cracks, it had become quite habitable and even dear to each of us. After all, it had justified our hopes and proved to be of great endurance and hospitable" [26].

In its 376 days of drifting, North Pole 3 followed a very complicated and sinuous course covering a total of 2,200 km to reach a point 830 km from where it started.

In April 1955, to replace North Pole 3, a new drifting scientific station—North Pole 5—was landed north of the New Siberian Islands at 82°11'N, 156°13'E.

The 1955 expedition not only kept the drifting station operating, but also carried out hydrological research in areas that had been studied least of all along that line—north of Franz Josef Land and in the area through which North Pole 3 had drifted.

In April 1956, the men working at North Pole 4 and North Pole 5 were relieved by new teams. At the same time, another station—North Pole 6—was set up on an "ice island"



The North Pole 13 station

14.5 km long and 11 km wide, that was located at 74°24′N, 182°57′E.

Thus, every year from 1954 on, at least two drifting scientific stations of the North Pole series have been operating in the central part of the Arctic Ocean. So far, a total of nearly twenty such stations have been set up, each one having replaced some other station that had completed its drift. The personnel manning stations that operated for several years at a time was exchanged annually.

Although each new team could take advantage of the experience accumulated by previous groups, and air service to the stations was continually improved, it was still no easy job operating the stations, and as before there was always the element of danger. In the summer when the ice began to melt and the ice fields would be surrounded by water, there was the danger that the fields would break up and drift apart. In the winter, there was the problem of compression, and work had to be carried on in the darkness of the polar night and in bitter cold. For example, in the

winter of 1964-1965, the North Pole 12 team had to carry on with their observations with the temperature holding steady at about —48°C. Earlier, in the spring of 1964, the ice field split right under the camp. The men had to throw up a bridge across the gap and, with the aid of a tractor, move their house and equipment to a more secure place. The North Pole 13 party also had to move their camp to another field for the same reason.

In early 1966, the North Pole 14 team experienced the same problem. When their field cracked, there was not enough room left near the station for even a small airplane to land, and the station had to be evacuated by helicopter. The helicopter crew, flying in terrible weather (this was in the first half of February 1966), and in the blackness of the polar night, made twelve trips to remove the station's men and equipment to the nearest island. It was the first such operation in the history of developing the Arctic.

The North Pole drifting scientific stations in the central regions of the Arctic Ocean continued their research in subsequent years and up to the present day. In 1973 and 1975, the North Pole 22 and North Pole 23 stations were established on floating islands of ice.

As the drifting stations of the North Pole series carried on their stationary observations, another systematic programme of high latitude exploration and research was being carried out by numerous aerial expeditions, in a series called Sever (North).

In 1957 and 1958, these expeditions, the drifting stations, and observatories and polar stations located on the islands and along the coast of the Arctic Ocean, all took part in the programme of the International Geophysical Year (IGY)*. The work included studies in the fields of aerology, meteorology, oceanography, geomagnetism, ionospheric physics, aurora, glaciology and cosmic rays.

* A special committee for IGY (Comité Spécial de l'Année Géophysique Internationale) was established in 1951 by the UN International Council of Scientific Unions. The Soviet studies were planned and coordinated by the Soviet IGY Committee. The IGY programme of research was one of the largest ever to be conducted on an international scale. Scientists and technicians from countries all over the world cooperated in a coordinated and systematic study of the Earth and its environment, investigating natural phenomena in the Earth's core, on glaciers, in the oceans and seas, in the atmosphere at different levels, and in space.

After the conclusion of the International Geophysical Year, the "North" high-latitude aerial expeditions continued their comprehensive research into the nature of the Central Arctic. About thirty such expeditions have already taken place.

The drifting North Pole stations continue to function today as bases for year-round observations and measurements. The information they gather gives a picture of meteorological and hydrological processes throughout the year. The aero-meteorological observations are important in forecasting navigation and flying conditions in the Arctic as well as the weather on the mainland.

In addition to the manned drifting stations, special expeditions every year set up scores of automatic radio-meteorological units in the Arctic Ocean. These drifting automatic stations pick up weather data and transmit them to shore-based radio stations. The information is used for weather forecasting and in the systematic study of ice drift.

The studies conducted in the Central Arctic have shown that there is no such thing as a second magnetic pole, as had been suggested by some scientists. What was thought to be the location of such a pole turned out to be the centre of a large magnetic anomaly extending along a narrow strip through the entire Arctic Ocean.

Soviet polar explorers have been gathering much important data about ocean waters and ice, the course of the currents and ice drifts in the Central Arctic, the structure of the upper atmospheric layers and the atmospheric processes that determine climate and weather. Data from high latitude meteorological observations are put to practical daily use in Arctic navigation.

Also under observation in the Central Arctic was the fauna, ranging from large animals, such as the polar bear and narwhal (mammal of the dolphin family), and to microscopic bacteria. It turns out that under the perennial pack ice of the North Pole region, the entire body of ocean water and the ocean floor are inhabited by bacteria. The same kind of microbiological processes occur here as in the other ocean expanses of the Arctic. This creates conditions for the development in the uppermost latitudes of the Central Arctic of various forms of animal and plant life.

Polar explorers have seen polar bears, polar foxes, seals, sea gulls, ducks, snow-buntings and many other kinds of

wildlife on drifting ice floes far from land and even in the immediate vicinity of the pole.

Some important geographical discoveries were made in the course of post-war study of the Central Arctic, the major one being the discovery of the underwater Lomonosov Ridge in the central part of the Arctic Ocean.

Prior to the discovery, it was generally believed that the central part of the Arctic Ocean was a depression with a level floor, with perhaps only small rises and uneven places. This notion was based on soundings taken by Fridtjof Nansen during the drift of the *Fram*, by the North Pole 1 party, and during the drift of the *Georgi Sedov*. However, those measurements did not take in the broad expanses of the Arctic Ocean lying between 150°E and 70°W. Thus, there was still a considerable blank space on the relief map of the ocean floor.

Soundings in that area finally led to the discovery of what is now known as the Lomonosov Ridge. In his day, M. V. Lomonosov, who was born in a northern coastal village*, took a great interest in the exploration of the polar regions and the Northern Sea Route, and even wrote a large work, entitled *A Brief Description of Various Voyages in the Northern Seas and the Evidence of a Possible Passage to Eastern India via the Siberian Ocean***.

It should be noted that conjectures as to the existence of an underwater elevation in the middle of the Arctic Ocean had been made before it was actually discovered. Fridtjof Nansen, the first to discover great depths in the central part of the ocean (he measured a depth of 3,850 m during the drift of the *Fram*), considered it quite possible that substantial elevations would be found north of the *Fram*'s drift course (and perhaps even land "on the other side of the pole"). Studying tidal currents, R. Harris in 1911 found that there was evidently some kind of obstruction along the path of the tidal wave, leading him to believe that the central part of the Arctic Ocean was not deep-water throughout its extent. The large shoal or land mass that he assumed was there was even shown on some maps as

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* At the mouth of the Severnaya Dvina near Kholmogory, Arkhangelsk region.

** That is, via the Arctic Ocean along the coast of Siberia and the Pacific Ocean.

Y. Y. Gakkel

Harris Land. That this hypothetical "land" is non-existent is now firmly established.

Soviet scientists had also felt that ridges and elevations must exist in the middle of the Arctic. Between 1946 and 1948, V. A. Tokarev, I. V. Maksimov and V. T. Timofeyev concluded on the basis of hydrological and aeromagnetic studies that one of the bottom elevations must extend from the New Siberian Islands to the continental shelf of Greenland or Ellesmere Island.

The first soundings to provide direct evidence of the ridge were made by an expedition in 1948, under the scientific supervision of geophysicist M. E. Ostrekin. One of the teams of oceanographers and geophysicists taking part in that expedition was headed by geographer Y. Y. Gakkel, D. Sc. Gakkel's party worked for a considerable length of time on an ice floe about 200 miles from the pole. It made numerous landings by plane, each time taking a measurement of the ocean depth, taking oceanographic observations throughout the entire depth of the water, and magnetic observations.

"Upon arriving at the designated point on April 18, 1948," wrote Gakkel, "we made a hole in the ice, set up the instruments over it, covered them with a tent and measured the depth. Then, after a short break, we lowered a series of bathometers, devices by which samples of water were taken at various depths for chemical analysis. The lowest of this series of bathometers was supposed to be in the bottom layer of water, 223 metres from the sea floor. Imagine our surprise when we pulled that bathometer up to the surface and found that it had not closed: it had apparently touched bottom. Indeed, the device even brought back particles of bottom sediment. We then had to make another sounding, whereupon we found that in the several hours of drifting since our first sounding, the depth had decreased

by almost 400 metres" [27]. It was clear that the ice floe on which the party was working had drifted over a rather rapid bottom incline. This prompted the men to make soundings more frequently than they had planned. With each sounding, the depth measurement grew smaller. The ice was apparently drifting towards the "watershed" of an underwater ridge. The smallest reading during the drift—1,290 m or almost 1,500 m less than the first sounding—was taken on April 27. After that, the direction of the drift was almost reversed, and the depth readings began to increase.

Upon returning from the expedition, the hydrologist of the Gakkel party, V. T. Timofeyev, processed all the oceanographic data collected, compared them with material from previous expeditions (the *Fram* and *Georgi Sedov* and North Pole 1), and showed conclusively that the water on either side of the ridge had some definite differences. This confirmed the supposition that the ridge extended across the entire ocean, forming a continuous barrier against the interchange of water between the two basins it separated. The same conclusion was indicated when the hydrobiological material collected by the expedition was processed: the planktonic organisms living on either side of the ridge turned out to be of different species.

The ridge was now indicated on the latest bathymetric maps* of the Arctic Ocean, but only roughly, for its overall configuration, to say nothing of the relief details, was still unknown. The only definite knowledge about the ridge was the depth profile along the drift course of the ice floe that had carried Gakkel's party, and that profile characterised only the slope on one side of the ridge, the side facing in the direction of the Pacific Ocean.

Further progress in determining the contour of the ridge and the depths along its crest was made by a high latitude expedition in 1949-1950. In 1954, an expeditionary detachment under I. I. Cherevichny and M. E. Ostrekin continued work in that area. The detachment broke up into several groups that worked simultaneously at different points. The

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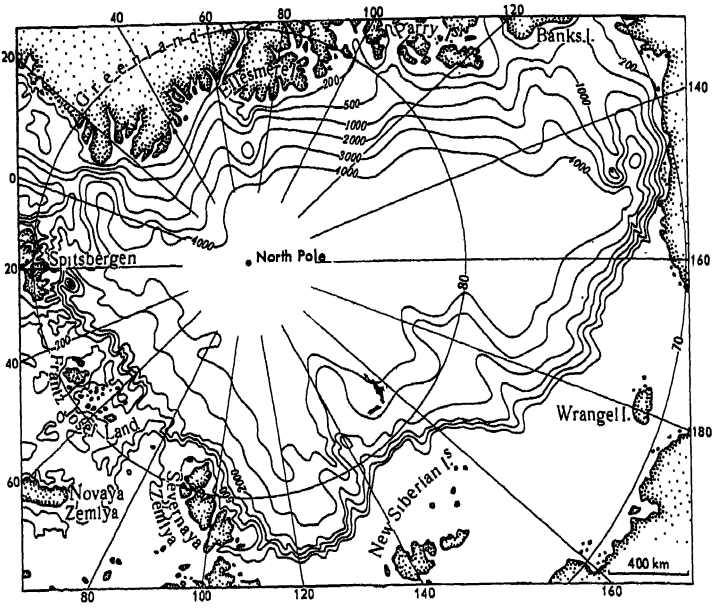
* A bathymetric map is a map indicating ocean depths. Depths are indicated by isobaths, or lines connecting all points having the same depth. Thus, the isobaths provide a detailed picture of the bottom contour.



Bottom relief of the Arctic Ocean prior to the discovery of the Lomonosov Ridge

ridge was gradually being "felt out", with each sounding adding to the overall picture of its crest, slopes and spurs.

The 1954 expedition added many significant details to the bathymetric map of the ridge. It sounded out, for example, what was then the highest known point—954 metres below the surface—along the crest of the ridge. In late August 1954, North Pole 3 drifted over the ridge and gathered important data. Specifically, it got a full cross section of the ridge near the North Pole.

The Lomonosov Ridge is approximately 1,800 km long, extending from the New Siberian Islands past the North Pole to Ellesmere Island. It rises 2,500 to 3,000 m above the ocean bottom, and in some places even higher than 3,000 metres. Along its crest, the depths are generally around 1,100 to 1,200 metres; in other words, the crest as a whole lies more than one kilometre below the water surface, although its contour is highly variable. In some places it has cols, while in others it has sizeable spurs extending from it. The ridge's slopes are fairly steep, reaching 25° in some places. The

spurs discovered by North Pole 3, however, have a greater slope than the basic ridge.

Analysis of bottom sediment has revealed argillaceous silt in the basins adjacent to the ridge, while on the ridge itself the silt is sandy.

North Pole 3 occasionally pulled up smooth pebbles from the slopes of the Lomonosov Ridge. Such pebbles have been extracted in large quantities from the sea bed in the polar region, from depths of a little over 3,000 metres. This apparently indicates that the ridge had once been above the surface of the ocean.

Geologists have been able to reconstruct the history of the central part of the Arctic Ocean for the last 50,000 years by studying cores from the ocean bottom and the remains of microfauna in it.

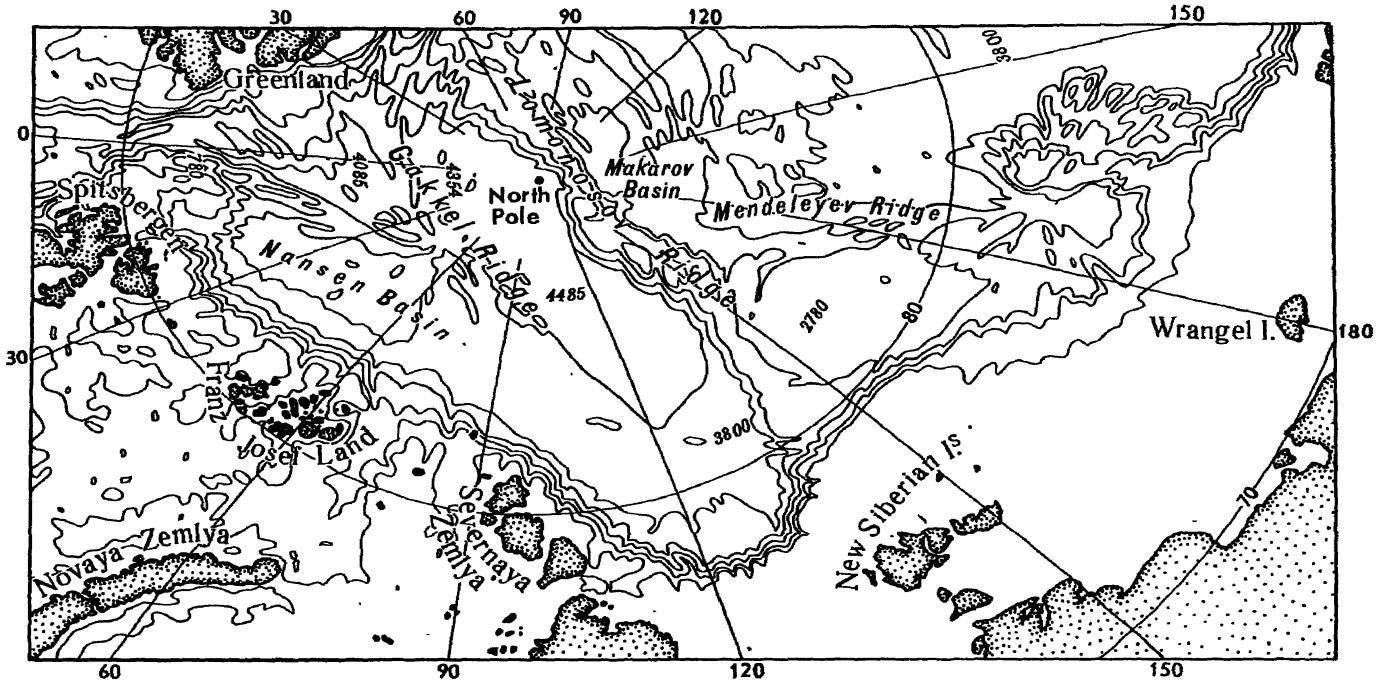
The Lomonosov Ridge plays an important role in the life of the Arctic Ocean, for it stands as a barrier in the way of deep water currents. For this reason, the properties of the water and the organic life in the two basins separated by the ridge are not the same.

Hydrological studies by Soviet polar explorers have shown that there is a much greater penetration of Pacific Ocean water through the Bering Strait into the Arctic Ocean than had been previously thought. Hence, two factors account for the distinctive properties of the water in the eastern part of the ocean: its isolation from the western part due to the Lomonosov Ridge and the interchange of water with the Pacific Ocean through the Bering Strait.

Besides the Lomonosov Ridge, Soviet polar researchers found other rises of considerable area. It turned out that the central part of the Arctic Ocean consists of several depressions divided by extensive and high rises and ridges.

One such ridge, lower than the Lomonosov Ridge but of comparable length and extending parallel to it in the direction between Wrangel Island and Ellesmere Island, is called the Mendeleyev Ridge. It is separated from the Lomonosov Ridge by the Makarov and Podvodnikov Basins.

On the other side of the Lomonosov Ridge lies another ridge, also running parallel to it. Drifting station North Pole 6 (1959) sounded one of its peaks at only 728 metres below the surface. Only five miles from there, the ocean reaches a depth of 4,320 metres. The bottom relief in that region is extremely complex. Not far from the peak men-



Bottom relief of the Arctic Ocean on present maps

tioned above lie the deepest depressions of the Arctic Ocean: the Georgi Sedov Trough*, with a depth of 5,335 m, and the Litke Trough, with a depth, measured in 1955, of 5,449 m, the greatest known depth in the Central Arctic and in the entire Arctic Ocean.

As a result of the latest soundings, this ridge now stands out clearly on the bathymetric map. In accordance with a decision of the Presidium of the Geographical Society of the USSR, dated April 26, 1966, the ridge was named after its discoverer, Y. Y. Gakkel.** Depths in the region of the Gakkel Ridge vary from several hundred metres to 5,000 and more metres in the rift valley that splits it lengthwise. The rift valley has been called the Valley of Hydrographers. To the west, far beyond the limits of the Soviet sector of the Arctic, the Gakkel Ridge joins the Knipovich Ridge (a name proposed by Gakkel), which lies on the extension of the Mid-Atlantic Ridge in the Greenland and Norwegian seas.

When it was learned that the Gakkel Ridge cut the Nansen Basin in two, the northern part was named the Arctic Basin, while the southern part retained its former name.

Lying to the south-east of the Lomonosov Ridge is the Podvodnikov Basin, and one of the bottom elevations of the Arctic Basin has been called Mount Leninsky Komsomol.

Soviet drifting stations have also determined some of the features of the bottom relief in the eastern part of the Arctic Ocean, sometimes even beyond the limits of the Soviet sector of the Arctic. For instance, the station North Pole 4 established the fact that the huge depression (with depths of up to 4,000 m) to the north and north-east of the Chukotsk Sea is connected with the Beaufort Sea depression (with depths of over 4,500 m) through a narrow deep water strait.

North Pole 2, North Pole 4 and other stations gathered more precise data on the extent and relief of the continental

* The latest studies have shown that the Georgi Sedov Trough, formerly considered to be a unit in itself, is actually connected with the Lena Trench (see Chapter 16) and both are parts of the rift valley of the mid-oceanic ridge. The rift valley is a graben formed during expansion of the Earth's crust.

** Shortly before that, Gakkel had proposed naming the newly discovered submarine ridge after O. Y. Schmidt. The name Otto Schmidt Ridge appeared on a map in the *World Atlas* published in 1967.

shelf and continental slope of Siberia north of the Chukotsk and the East Siberian seas. The continental slope of Siberia is much steeper and extends considerably further north than was formerly thought; and the continental shelf is of a much larger area.

It was established, for example, that north of the Bering Strait, the continental shelf, which has the shape of a submarine peninsula with canyons cutting across it, extends almost 600 kilometres further north than previously shown. North Pole 4 found a canyon over 1,200 metres deep cutting across this submarine peninsula. In the Pole of Relative Inaccessibility area, the same station located a bottom rise with a sounding of 1,320 metres, connected with the northern part of this peninsula.

The topographic relief of the continental shelf is not as smooth as was generally believed, for it contains depressions with abrupt, steep sides. The origin of these depressions, in the opinion of Academician D. I. Shcherbakov, is connected with the sinking of the Earth's crust along fracture lines.

New concepts have been advanced about the structure of the bottom of the central part of the Arctic Ocean and its submarine mountain ridges by Soviet scientists (R. M. Demenitskaya, O. K. Leontyev, G. B. Udintsev, V. F. Kanayev, S. A. Ushakov, and others). Geophysical studies have shown that the bed of the Arctic Ocean is composed of an oceanic type of Earth's crust, and this applies also to the Lomonosov and Mendeleyev ridges.

After the Gakkel Ridge was discovered and it was learned that its location coincided with the belt of earthquake epicentres passing through that region, and that it is an extension of the Mid-Atlantic Ridge, there was every reason to conclude that that submarine ridge is part of the system of mid-oceanic ridges of the World Ocean.* And this further underscores the common features in the structure of the Arctic Ocean and other oceans.

Thus, during the post-war years Soviet polar explorers have penetrated many secrets of the Central Arctic and have

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* The mid-oceanic ridge system includes the extension of the Mid-Atlantic Ridge, known as the Knipovich Ridge, and its further extension, the Gakkel Ridge. The most recent research has confirmed that it bears all the features typical of mid-oceanic ridges.

made some outstanding discoveries. This has been the result of the comprehensive arctic research carried on by scores of airborne expeditions and drifting stations. Many more interesting facts will come to light as data received is processed.

We are now on the threshold of a new era in the exploration and development of the Arctic. The study and conquest of the icy arctic expanses is enhanced by rapid advances in technology. In addition to the AN-2, IL-2, IL-12, IL-14 and other aircraft that have been used in scientific work, Aeroflot's polar aviation has begun large-scale use of AN-12 turboprop liners. The MI-4 helicopter has become thoroughly "acclimatised" to the Arctic. And ploughing the endless ice expanse of the Arctic Ocean are the powerful diesel-electric icebreakers of the *Moskva* type and the nuclear-powered icebreaker *Lenin*.

CHAPTER 4

EXPLORATION OF THE ARCTIC AND SUB-ARCTIC EXPANSES OF NORTHERN SIBERIA. THE TAIMYR EXPEDITIONS

A simple glance at the map of Russia shows that her main façade faces the Arctic Ocean.

S. O. Makarov

To the east of the polar Urals stretch the endless expanses of distant and forbidding Northern Siberia. Despite the remarkable and fruitful efforts of Russian explorers, especially of those taking part in the Great Northern Expedition (1733-1743), the entire northern coast of Siberia remained poorly charted, while huge areas of tundra lying deep inland remained totally unexplored and appeared as large blank spaces on the pre-revolutionary geographical maps.

As a result of Soviet exploration, the map of the northern coast of Siberia has changed markedly. The contours of the northern shore of the Gyda Peninsula have changed beyond recognition: Shokalsky and Oleny islands have appeared close by, and the curving Gyda Gulf penetrating deep inland takes a large river (the Yuribei) from the south-west, and not from the south-east as was shown on the old maps. Flowing into the gulf from the east is the Gyda River, taking its origin from Lake Khosein-To located not far away.

The sea of the Gyda Peninsula and the Gyda Gulf were explored by Soviet hydrographic expeditions in the 1920s. The expedition of 1922-1923 on the schooner *Agnessa* established the fact that capes Mata-sale and Tara-sale, which

were shown on pre-revolutionary maps as being at the northern end of the Gyda Peninsula, were actually located on islands (Shokalsky and Ovtsyna islands). A survey made by that same expedition showed that the Gyda Gulf extended far to the east in an almost latitudinal direction, whereas on former maps it was much shorter and meridional.

The contour of the Taz Gulf and the Pur River flowing into it were also markedly changed on the map.

In 1923, an expedition under B. N. Gorodkov, known as the West Siberian Expedition, went from Surgut, located on the river Ob, and travelling along the Agan and Pur rivers, reached the Taz Gulf. On its way back, it took a direct winter route across Lake Pyaku-To. That expedition gathered a considerable amount of new cartographic data on the Pur River basin. Information as to the names of the river's many tributaries was supplied by local inhabitants who accompanied the expedition.

A survey of the lower reaches of the Taz River was made in 1926-1927 by the Taz Expedition of the Geographical Society, under R. E. Kols. Former maps of the area were highly inaccurate. An atlas of the lower reaches of the Taz River, compiled by Kols, was published by the Geographical Society in 1928.

Of the huge area between the lower reaches of the Yenisei River and the Ob-Taz Gulf, only a small part around the upper reaches of the Gyda, visited by Academician F. B. Schmidt in 1886, had been studied prior to the October Revolution. That region was explored by the Gyda Integrated Expedition of the Standing Polar Committee, of the Academy of Sciences, under B. N. Gorodkov (1927). Simultaneously, an expedition of the Northern Sea Route Committee worked along the coastline west of the mouth of the Yenisei River, making surveys, geographical descriptions and conducting hydrographical studies.

In addition to making a comprehensive study of the Gyda tundra (its topography, geological structure, soil, vegetation, etc.), the Gyda Integrated Expedition under B. N. Gorodkov also made astronomical determinations and a survey of the region. The route survey was made while travelling by reindeer, dog sled and boat. The distances travelled throughout the Gyda Peninsula in the course of this work added up to about 5,000 km.

* * *

Major corrections have been made in the map of the Taimyr Peninsula, both in respect to the contour of its coastline and to the geography of its internal part, where Soviet explorers have eliminated a huge blank space.

Upon completing a journey across the Taimyr Peninsula in 1843, Academician A. F. Middendorf wrote: "Another hundred years will pass, perhaps, before some other traveller will venture to break the silence of this wilderness with the aim of adding to our knowledge of this curious region..." [28]. He was almost right; his prediction was off only by some fifteen years. On pre-revolutionary maps, printed across the Taimyr Peninsula, the northernmost peninsula in Siberia, was the word: "Unexplored".

It appears that in pre-revolutionary times, Taimyr had indeed been visited only once every hundred years. Middendorf wrote the following about his predecessors, members of the Great Northern Expedition: "A whole century has passed since Laptev and Chelyuskin, under inexpressibly difficult and dangerous conditions ... succeeded in surveying the coast of Taimyr. We are obliged to them for an approximately accurate outline (meaning the contour of the coastline—*N. G.*) of this peninsula and its extremities" [29]. Thus, there was an interval of 100 years before Middendorf "filled in the frame that had remained empty after them", that is, mapped some of the internal features of the peninsula. After that, many more decades passed before the peninsula was explored again.

After the October Revolution, the task of developing the Northern Sea Route and the northern outskirts of the country demanded that the veil of obscurity be lifted from the vast territory of Taimyr. And so, Soviet expeditions began to penetrate this remote, almost inaccessible northernmost region of the country's mainland. In fact, over the years of Soviet government, the Taimyr has seen many more expeditions than the entire Arctic had seen in pre-revolutionary times.

Soviet expeditions discovered mountains rising more than 1,000 metres above sea level, studied the vegetation and animal life in the tundra, and made a comprehensive study of Lake Taimyr. For the first time in history, the Pyasina River and Lake Taimyr were shown accurately on the map.

Important geographical data were gathered by the Taimyr Expedition of the Academy of Sciences of the USSR, undertaken in 1928 under A. I. Tolmachev. Its objective was to explore the Lake Taimyr area and the inner part of eastern Taimyr.

Even while still en route to where the expedition was to conduct its basic work, "moving eastward away from the Pyasina River ... substantial errors in the map were noted, and an astronomical determination on the Avama River showed a shift of about 50 kilometres to the north as compared with the map".

Investigations in the Lake Taimyr area showed "a complete lack of correspondence between the map and the actual contour and size of Lake Taimyr". It turned out, for example, that the lake stretched 4° further to the east than indicated on the map. A more accurate representation of the Byrranga Range was made and many new smaller ranges were discovered. One of these mountain masses was discovered south of Lake Taimyr, which had previously been considered the "boundary between the mountainous northern and relatively flat southern parts of the Taimyr". On their way back, the explorers found that Lake Taimyr itself extended much further south than former maps had shown [30].

An important contribution to the scientific study of the Taimyr Peninsula was made in 1929 by the Taimyr Expedition of the Geological Committee of the USSR, which worked under the direction of N. N. Urvantsev. That expedition gathered a great deal of new information on the orography and hydrography of the region, determined the characteristics of its geological structure, and discovered clear traces of extensive ancient glaciation. Urvantsev had observed traces of past glaciation in the western part of the Byrranga Mountains before, when he had conducted the exploration of the northern part of the Central Siberian Plateau and of the Taimyr Peninsula (1919-1926). A substantially different picture of the topographical relief of the Byrranga Mountains resulted from the work of the 1929 expedition. The expedition conducted a large-scale semi-instrumental route survey*, which was based on astronomical points determined by its geodesist.

* In a semi-instrumental survey, some of the measurements (for example, the measurement of angles) are made with geodetic instruments, while others (for example, the determination of distances)

On the basis of route surveys and materials already on hand (Middendorf's and Tolmachev's surveys), Urvantsev drew up topographical and geological maps of the Nizhnyaya Taimyra River, the Taimyra River basin and the northern part of Turukhansk region (today the Taimyr [Dolgano-Nenets] National Area).

Research carried out by the Arctic Institute has done much to fill in the Taimyr blank space.

The Taimyr's remoteness makes its exploration complicated. One expedition working at Lake Taimyr in 1943-1944, first had to go about 1,000 kilometres of tundra by reindeer, then proceeded to the lake by river in boats. It wintered on the shores of the lake in coal-heated tents, and conducted scientific observations throughout the winter. A special airplane was sent to bring the expedition back.

While the first Soviet expeditions to the Taimyr (Tolmachev's, Urvantsev's and others) used primarily boats, dog teams and reindeer, later expeditions began to use half-tracks, and airplanes were used in making surveys. Radio equipment became a regular part of the gear for all expeditions. Radio communication kept the explorers in touch not only with their bases, but with the whole country. Sturdy buildings, brought in on the Northern Sea Route, were erected for winter quarters. But even in those new conditions, work in the Taimyr tundra was not easy.

"You don't dare put away your winter hat and padded jacket for the summer: one moment, the sun will be hot, but an hour later the tender green grass may be covered with wet snowflakes. You cannot find edible berries and mushrooms here. Only rarely, if the sun happens to dry out the lichen growing on rocks, can you use the lichen to make a fire to boil water in your tea kettle, thus economising on precious kerosine."

When it came to exploring some area on foot, the men had to carry everything, from tinned food to sleeping bags and tent pins. Every step led to discovery, but at the cost of great effort. "Your feet sink in the thawed out earth, or

with simple devices that are used in a so-called eye survey. A semi-instrumental survey is less accurate than an instrumental survey, but more accurate than an eye survey.

you come across vast rock fields, or you have to spend days to find a suitable place to ford a rushing, cold river" [31].

The Taimyr tundra comes to life in the summer. In that remote wilderness, the explorer frequently encounters animals that have never seen human beings. A young polar fox may come right up to your tent, sniffing at the unfamiliar odours and ignoring the sounds of laughter and conversation. But the click of a camera will frighten him and he will jump back and yelp at the guests hoarsely. In the grassy valleys, reindeer graze, carefully carrying their branched horns that have not yet ossified and are covered with velvety skin.

The shrub-like polar willow that spreads itself over the ground is a pleasant sight to the explorers. If you lift it off the ground, it will not be any higher than a man in a squatting position.

* * *

In 1933, a polar station was established at Cape Chelyuskin, the northernmost point of the Taimyr Peninsula and of the entire mainland of Asia. That year marked the beginning of a systematic geographical study of the coast. In place of the former descriptive work, instrumental surveys on a firm geodetic base* began. The geographical map of the

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* A firm geodetic base, or a geodetic control network, is a system of points whose location is determined by land measurements made with instruments. The location of geodetic control points is determined primarily by the method of triangulation, which is based on the trigonometric principle of distance determination. Chains or nets of triangles are set up, in which the consecutive triangles are joined by their common sides (markers or special towers, called signals, are placed at the corners of the triangles). A side of one triangle, called the base, is measured with great accuracy (using a tape measure or a special wire). The angles of the other triangles are then measured with geodetic instruments, and the distance from the starting to the end point is computed trigonometrically. A geodetic control net must be tied to a point whose geographic coordinates—latitude and longitude—are known. In remote, little-explored places, these may be astronomical points determined by very careful observation. As in the case of astronomical points, the points of a geodetic control net are used as a base for making topographical surveys. But since they are arranged more densely than are astronomical points, it follows that accurate and detailed topographical surveys (instrumental land surveys or aerotopographical surveys) are generally made

coast was gradually corrected and filled in with details. And accurate sea charts were drawn up to meet the needs of navigation.

Major work in correcting and improving the accuracy of the map of the Taimyr Peninsula coast was done in 1940-1941 by the Eastern Taimyr Expedition of the Hydrographical Department of the Northern Sea Route Administration. Under study was the large stretch of coast from Cape Chelyuskin to the Bay of Maria Pronchishcheva, that is, from the northernmost to the easternmost parts of the peninsula.

It was a 38-man expedition (including geodesists, topographers, hydrographers and other specialists), headed by astronomer and geodesist A. I. Kosoy, who had frequently been in charge of work in poorly known areas of the North. The expedition had precision instruments, radio equipment, a small sounding ship—the *Nord*, a motor boat and cross-country vehicles.

The expedition was outfitted in Leningrad and Arkhangelsk. From Arkhangelsk, one group (the marine detachment) went with part of the equipment and supplies in the *Nord*, while the main part of the expedition travelled to its destination on the icebreaker *Dezhnev*.

It was mid-September when the *Dezhnev* reached the Taimyr Peninsula.* The coast looked cheerless and barren. Only the mountain range lying further south brightened the landscape a little. The tundra plants had already faded and everything around had turned a dirty yellow colour.

"Wherever we stepped," wrote Kosoy, "water would ooze out of the earth, and we searched in vain for a dry area on which to build a base. The narrow pebble beach could serve only as a temporary place for unloading our cargo, and even it was half full of big chunks of ice that had been washed ashore..." [32].

First, a small tent city went up on the barren shore, and then began the construction of three wooden houses to serve as the expedition's base.

On the very first day ashore, three polar bears came visiting. "They were met with gladness and even brought into

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on a firm geodetic base. Astronomic and geodetic observations in expeditions concerned with surveying are taken by geodesists. The actual surveying work, or the decoding of aerial photographs in the case of aerotopographical surveys, is done by topographers.

* The marine detachment on the *Nord* had arrived a month earlier.

the camp on a vehicle, albeit in the form of dead carcasses. The lucky hunting provided a long-lasting supply of wonderful fresh meat for both the men and the dogs..." [33].

At one point during the marine detachment's autumn geodetic work, a dog team pulling a loaded sled fell through the ice. The men were able to retrieve the camping equipment from under the ice, but twelve of their best dogs drowned. It was a serious blow to the expedition's transportation.

Due to the carelessness of one of the members of the expedition, the radio shack burned down. It had to be rebuilt at a time of bitter cold and blizzards and in the darkness of the polar night that had already begun. More trouble came one day when a geodetic party that had gone out on reconnaissance in a cross-country vehicle was long overdue in returning to the base. A search party went out on another cross-country vehicle, and that one, too, broke down. Both vehicles had to be left in the tundra.

Trips away from the base were suspended in December for the rest of the darkest months of the polar night. In February, a repair team went into the tundra to repair and bring back the abandoned vehicles. On the way, the team reconnoitred and set up signals (pyramids) for geodetic observations. In March and April, the work of the marine (hydrographic) and land detachments was in full swing. Some parties were brought in from the neighbouring region by airplane.

By the end of May, the spring programme of field work was completed, and the parties made ready to return to the base. Now that the basic geodetic work was done, topographical surveying could begin. In June and July, the topographical parties of the land detachment set out into the tundra by dog sled. The party that was completing the geodetic work drove out by cross-country vehicle. On the way, it dropped off the men and supplies of the last topographical party at their work location.

The summer now hampered the field work considerably. Warm sunny days began to melt the snow, and in the bays, water accumulated on top of the ice, so that the geodesists sometimes had to work knee-deep in water. "In some places, the water was so deep that it went over the top of our hip-boots. Measurements were possible only because the ice underneath was motionless. We had to hurry not only for fear that the rapid melting would break off the measure-

ments, but also because every extra day of delay reduced the chances for a safe return of the cross-country vehicle..." [34].

Excerpts from the diary of topographer and geodesist N. S. Yudov, one of the leaders of the party, describe the conditions under which the topographers had to work:

"June 30. There is no snow on land at all; movement across the ice has become very difficult because of the breaking ice. We came across a crack over four metres wide, extending from the shore to the open water in the sea. We got across the crack on an ice floe, since there was no other way. Further ... the ice was drifting; the fast ice consisted of blocks separated from each other by cracks ten metres wide. It took about 6 hours of hard and risky work to cross a distance of two kilometres with loaded sleds."

"On July 16 ... a heavy rain started and continued for two and a half days. We could see the ice melting right before our eyes. In the same area we had traversed on July 16 with loaded sledges, on July 18, on our way to work without anything, even without dog sleds, we had to use individual blocks of ice as rafts, and on the way back we were up to our waists in water in two places.

"On July 19, we made another attempt to get from the island to the mainland, but failed. We succeeded only on July 20, and once we had crossed the strait we, along with all the dogs, dragged the loaded sledge over sand and pebbles for about two kilometres..." [35].

The topographical parties of the marine detachment also worked under difficult conditions. During the thaw and slush period they had no dog sleds and had to carry all their gear from campsite to campsite on their backs.

Topographer N. I. Linnik described one episode during the expedition as follows: "Kasyanenko and his men came over from Vilkitsky Island to where we were on the Lasinius Peninsula; they could stay on the islands no longer without the risk of being cut off from the mainland for a long time because of the water. The water was already waist-deep in places, but despite all the difficulties, they got all of their gear safely to Cape Lasinius, hauling it by sledge in some places, and on their backs, in others. The picture is no better in Sims Bay: a large segment of it (in the southern part) is ice free, and while there is still ice closer to the sea, it is full of cracks. The situation is getting worse day by day,

and although we have only two days' work left, we have to return to the base....

"...It was decided that we should head for the ship. All our provisions, except for rice, are exhausted. Kasyanenko's party was the first to go across Sims Bay. Once they got to the east shore they were to build a campfire, the smoke from which would serve as a signal for us to start out. Five hours later we saw the smoke, and loading our sleeping bags and instruments (about 25 kilogrammes per person) on our backs, we set out across the bay. The six to seven mile crossing took us five hours. After drying ourselves by the fire, we once again got down to work" [36].

It was during those months of hard and strenuous work that the explorers learned about the outbreak of the Great Patriotic War. Awareness of the responsibility that every Soviet citizen had for the fate of his country made the members of the expedition regard the fulfilment of their assignment with even greater exactingness.

In August, all the work having been completed, the main body of the expedition's personnel sailed on board the steamship *Sibiryakov* from Dikson to Dudinka (on the Yenisei), and from there by river boat to Krasnoyarsk.

The expedition carried out a large volume of astronomical and geodetic work, took geomagnetic observations, made a topographical survey of the coastal strip from the north-western shore of Klavenes Bay (at Cape Laptev) to the Bay of Pronchishcheva, including Vilkitsky, Faddei, Andrei, Pyotr and other islands located near the mainland, and also some newly discovered islands. During the survey of the shoreline, new bays were discovered.

As a result of the work done, the outlines of the explored part of the coast and of the nearby islands, as shown on the geographical map, were altered.

The expedition also made a thorough study of the relief of the sea floor along the coast, on the basis of which the hydrographic maps and pilot books* for the region were corrected. Navigational markers built by the expedition simplified navigation.

The topographers and hydrographers of the marine detachment made some outstanding archeological finds, which

* Pilot books, or sailing directions, give a detailed description of the navigable part of a coast and contain information explaining and supplementing navigational charts.

threw much light on the history of Russian northern navigation in the early 17th century.

* * *

The use of aircraft in exploring the Taimyr Peninsula made it possible to get accurate data on the elevations and topographical relief of the Byrranga Mountains and an overall picture of the hydrographic system of the peninsula, which abounds in rivers and lakes.

According to data compiled by geographer A. B. Vinnik (in 1955), the Byrranga Mountains are not a plateau but a mountain system consisting of a number of mountain ridges and masses broken up by river valleys eroded by glaciers. A sizeable glacier was found in the mountains and given the name Neozhydanny (Unexpected). Later, a whole mountain-glacier region was discovered in the Byrranga Mountains with a dozen large valley glaciers (to 5 km in length) and more than a hundred small kar-type ones.

The beautiful but forbidding mountain rivers of the peninsula are fast flowing. In the Malakhaitari River valley at approximately 74°N grow willow shrubs up to two metres in height. The northern timberline in the Taimyr Peninsula area is strongly pronounced. Beginning immediately to the south of the tundra lies the sparse taiga. There is hardly any forest-tundra at all. Further to the east, along the right bank of the Khatanga, the northern boundary of the sparse taiga is also clearly defined. The solid tract of forest there goes as far as 72°32'N.

Field work was also carried out along the Siberian coast east of the Taimyr Peninsula, after which noticeable changes appeared on the map with respect to the configuration of Olenek Bay and the Lena River delta. With the help of aerial photography, excellent maps have been drawn up showing all the geographical features of that distinctive area. The map representation of the mouth of the Indigirka River has also undergone substantial changes.

All of this has been the result of exploratory expeditions carried out in Soviet times in the distant Siberian territory.

CHAPTER 5

DISCOVERY OF THE CHERSKY RANGE AND EXPLORATION OF THE KOLYMA BASIN

His expedition of 1926 to the Verkhoyansk Range and the Indigirka River basin ... led to outstanding geographical achievements, the most unexpected of which was the discovery of the gigantic Chersky Range ... the last large range to be discovered in either the Old or the New World.

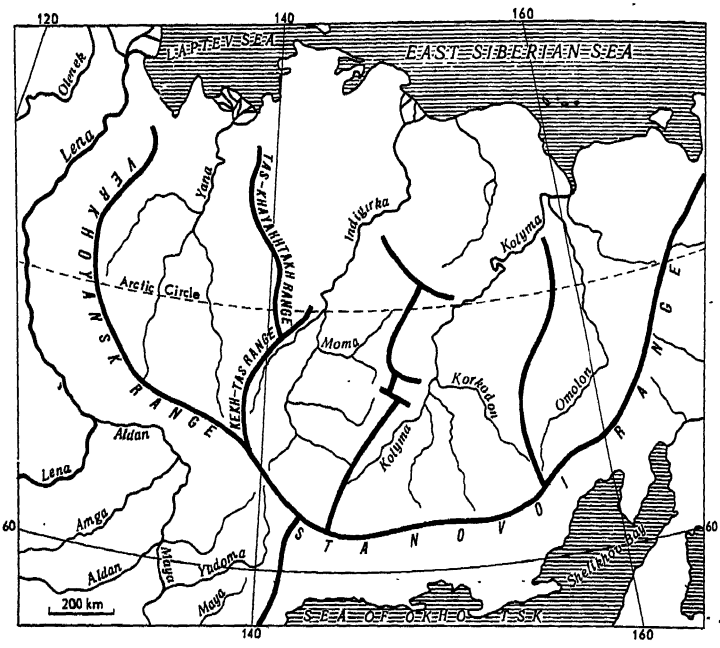
From the obituary of S. V. Obruchev

As a result of Soviet explorations, the geographers' conception of the arrangement of mountain ranges and river valleys in Northeastern Siberia has undergone a drastic change.

Lying within the arc formed by the Verkhoyansk and Stanovoi (Kolyma) ranges, the 1916 map showed a system of mountain chains and ridges stretching basically to the north-east, parallel to the major rivers (the Yana, Indigirka and Kolyma), and forming, as it were, watersheds between them. Today's map shows, within that same arc, a great system of parallel mountain chains running north-west to south-east, that is, transversely to the direction of the major rivers of the Kolyma-Indigirka region (see maps on pp. 78-79).

This mountain system, called the Chersky Range, was discovered in 1926 by the expedition of geologist S. V. Obruchev. The most impressive result of the work of that expedition, which had penetrated a totally unknown area, was the discovery of a massive range in a place that was thought to be a lowland region. That discovery was so interesting and important that it warrants a more detailed discussion here.

In the 17th century, Russian travellers, who in those days were primarily Cossacks and merchants, penetrated what is known as the Lena-Kolyma, Yukagir and Chukot



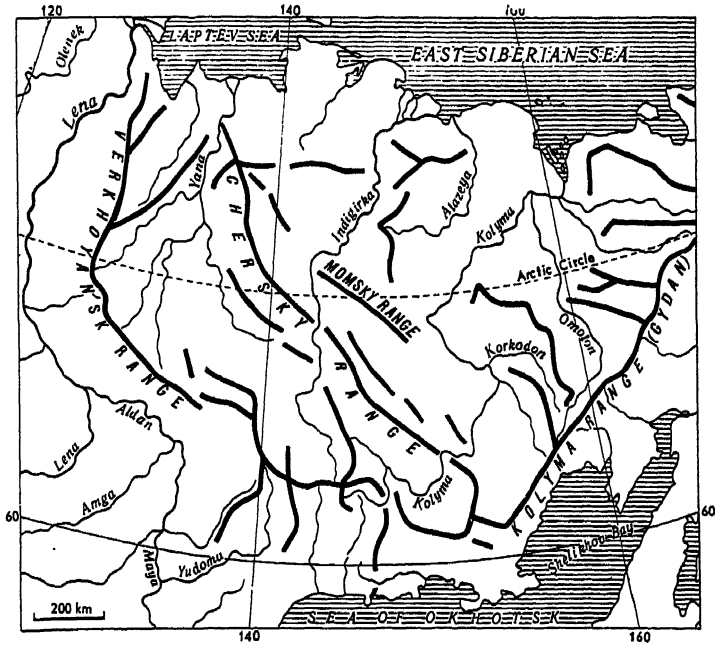
Arrangement of mountain ranges in the Kolyma-Indigirka area as shown on maps prior to S. V. Obruchev's 1926 expedition

lands—the basin of the Lena, Yana, Indigirka, Kolyma and Anadyr rivers, and the Chukotka Peninsula all the way to the Bering Strait. Predatory exploitation of the local natural riches, above all the fur-bearing animals, exhausted this region and led to the impoverishment and extinction of the indigenous population. The tsarist government showed little interest in the scientific exploration of the region. A few scientists, among whom was the remarkable Russian traveller of the late 18th century, naval captain G. A. Sarychev, had traversed the region obliquely.

One of those who had explored the region was the noted geologist and geographer Ivan Chersky, in whose honour the later to be discovered mountain range (or mountain system, to be exact) was named.

In the late 19th century, Chersky was sent by the Academy of Sciences on a three-year mission to explore the Verkhoyansk-Kolyma region.

Chersky, his wife, who was the expedition's zoologist and their 12-year-old son, set out from Yakutsk in June



Arrangement of mountain ranges in the Kolyma-Indigirka area as shown on maps after S. V. Obruchev's 1926 expedition

1891. After passing over Verkhoyansk Range and crossing the Indigirka River at Oimyakon, they proceeded further to the north-east over the Taz-Kystabyt Range. On August 28, they arrived at the village of Verkhnekolymsk, and there they wintered.

A man of frail health and a victim of lung disease, Chersky fell seriously ill during the winter. Realising that his days were numbered, he made haste to finish what he had set out to do. In the spring of 1892, the expedition set out again, this time down the Kolyma River.

As he was leaving Verkhnekolymsk on May 31, 1892, Chersky said to one of the local inhabitants: "At the very best I hope to last another three weeks. Any longer is improbable." Only a man of extraordinary determination would, knowing the hopelessness of his situation, resolve to travel on! "I have given instructions," he continued, "not to break off the expedition before reaching Nizhnekolymsk even if my last minutes are approaching, and to keep carrying me forward even as I am expiring" [37]. Chersky felt it was

imperative to get as far as Nizhnekolymsk in order to complete the exploration of the lower reaches of the Kolyma River.

Until June 10, he was still able to travel by boat. He would sit up at the bow of the boat, giving instructions to his wife and son as they examined the cliffs they were passing. On June 10, the party reached Srednekolymsk, but by June 20, Chersky had become so weak that he could not even write. He turned over the entire job of taking notes to his wife. In the notes she recorded during the last six days of her husband's life, geological and meteorological observations alternated with short tragic remarks: "My husband's condition is worse. He is getting weaker and weaker."

Chersky died on June 25, 1892 (Old Style) near the mouth of the Proïva River. On July 1, he was buried on the left bank of the Kolyma, opposite the mouth of the Omolon. His wife carried on with the observations and diary, but naturally could not continue that difficult work for long. Finally, she and her son returned to Yakutsk.

And so, that unknown land remained only partially explored. To be sure, Chersky's collections and diaries were brought to St. Petersburg and are now preserved at the Academy of Sciences. In 1892, while wintering in Verkhnekolymsk, Chersky compiled a preliminary report on the first year of his expeditionary work, and sent it to the Academy. This material, disclosing new data on the geological structure and geography of the region, was published in 1893. However, Chersky's explorations had covered only a narrow strip.

The most important geographic discovery made by Chersky was the following. He found that beyond the Verkhoyansk Range lie three high mountain chains: a range, which he named Tas-Kystabyt, located on the right bank of the Indigirka above Oimyakon, and the Ulakhan-Chistai and Tomuskhai ranges at the watershed of the Indigirka and Kolyma rivers. Chersky's indication that the ranges of that region extend to the north-west and not to the north-east (as depicted on earlier maps) was ignored by cartographers, and until Obruchev's expedition, maps continued to show the same radial ranges, but with the chains discovered by Chersky added. If Chersky's expedition had not ended so tragically the curtain over that enigmatic land would have been lifted at the end of the 19th century.

For a period of 35 years after Chersky's death, the south-eastern part of the Verkhoyansk-Kolyma region remained virtually unvisited by expeditions. It was only in Soviet times that the exploration begun by Chersky could be continued. This was done in 1926 by Obruchev's expedition, which discovered, as mentioned earlier, a high mountain chain — or, more exactly, a whole mountain country — in an area that had been shown on the map as lowlands.

Shortly before his death — on June 3, 1892, to be precise — Chersky said jokingly to one of the inhabitants of Verkhnekolymsk: "Actually, I am not afraid of death: everyone has to go sooner or later. I am glad, though, that I am dying here, in these distant parts; many many years from now some geologist may find my body and send it for some reason or other to a museum, and that way I will be immortalised" [38].

Chersky's wish to have his memory perpetuated has been fulfilled, but in a different way: "... His monument is 1,000 kilometres long, 300 kilometres wide and up to 3,000 metres high; bigger in area than the Caucasus, and higher than all the mountains of Northern Siberia. It is perhaps the last large range that can be discovered on Earth." These were the concluding words in S. V. Obruchev's book about his journey to the Indigirka and his discovery of the Chersky Range [39].

The discovery of the Chersky Range was one of the most outstanding discoveries in our country in Soviet times. How was it made?

* * *

When in 1926 Obruchev undertook his expedition to study the western part of the Indigirka basin, he had before him an arduous journey over the mountains and endless forests and swamps to the north-east, and over the Verkhoyansk Range to the Chibagalakh River, a tributary of the Indigirka, where no explorer had ever been before.

The expedition consisted of Obruchev, geodesist K. A. Salishchev, mining engineer V. A. Protopopov, mining technician I. N. Chernov and two gold washers who joined the expedition in Irkutsk.

Preparations for the expedition were being made in Yakutsk. Obruchev learned that a promise had been made the previous winter to have food supplies delivered from Oimyakon to Chibagalakh, but he had no way of determining

whether it had been fulfilled. The horses for the expedition were ready and waiting when the party arrived in Yakutsk.

The day of departure was June 15. It took two days to get the caravan of 44 horses, 32 of which were carrying packs, across the Lena to the right bank, and from there it headed east towards the Aldan River valley. There the river reaches widths of up to ten kilometres, with numerous tree-covered islands breaking it up into channels sometimes one to two kilometres wide. After crossing the river with great difficulty (the horses swam across behind the boat carrying the men), the expedition stopped off in Krest-Khaldzhai, where a guide was hired. On July 3, they left Krest-Khaldzhai to continue their journey.

An arduous trek through swampland brought the exhausted men and horses to the bank of the Tompo River. From there, lying only a little further east, the outermost chain of the Verkhoyansk Range could be seen. The crossing was, as always, very difficult, but the range was close by and Obruchev and his companions were impatient to get there quickly. On the other side, they let the horses graze while Obruchev and Protopopov headed downstream to study the features of the Verkhoyansk Range's fringe. By evening they came to the mouth of a big river, a left tributary of the Tompo, the Menkyule.

Since it was late, they decided to camp overnight. They built a fire and, after it had burned for some time, put their sleeping bags by the side of the fire on warm ashes. "The Menkyule flows here in a depression running behind the outer chain, and the Tompo comes to meet it from the north, although according to the maps we had it was supposed to be flowing from the east," Obruchev later wrote [40]. Their map corrections began almost from the very beginning.

Early the next morning, Obruchev and Protopopov started back, but on the way they climbed the Kyurynyu, a mountain near the Tompo. From there they got a good view of a high chain of mountains — to which Obruchev gave the name Skalistaya — with heights of up to 2,000 m.

The next day, the caravan went up into the mountains, going deep into the Skalistaya chain, crossing over to the eastern slope of the range and down it along the ravine of one of its streams into the Menkyule River valley. Turning off from the Menkyule, they followed one of its tributaries through a deep and dusky valley.

Finally, the caravan climbed the main chain of the Verkhoyansk Range and came to a pass approximately 1,600 metres above sea level. Looking to the west they could see sharp ridges up to 2,500 metres high, with cirque-like indentations formed by ancient glaciers on the slopes near their crests. The crests themselves were covered with snow. To the east lay a level valley, with rounded mountains rising up beyond it. The mountains were treeless, but their slopes were covered with grass. Here the Evens spent the summer with their herds. The expedition descended into a wide valley at the upper reaches of the Tompo where it came across a group of Even tents and a herd of reindeer.

From there, the caravan moved eastward over some low grass-covered hills at the upper reaches of the Bryungyade River. This was already the Indigirka basin. In another two days, the expedition reached a big mountain chain intersected at right angles by a river. Obruchev named this mountain chain the Bryungyadinskaya. The party had to ford the river several times — a difficult and dangerous undertaking because the river was swollen after the rains. After crossing over a mountain ridge, the party reached the Bolshoi Selerikan, a large tributary of the Elga. From that point on, the guide could not remember the way and spent much time wandering through the swamps and thickets of young larch trees in search of a path.

South of the Bolshoi Selerikan River valley the travellers climbed up to a pass, and there below them on the other side lay a wide, wide valley. In the distance, still visible in the twilight, was a body of water, the reaches of a large river. It was the Indigirka. "The sight of it thrilled me," wrote Obruchev. "A river that no one had ever sailed, famous for its rapids. A totally unknown region in which no explorer had ever set foot. The mysterious Indigirka, which suddenly transformed from a geographical name into a reality, from a thin black strip on a map into a wide, coursing river" [41].

On July 29, the expedition descended into the Indigirka valley with its luxuriant meadows divided one from the other by larch groves. It was decided to go north, towards the mouth of the Elga.

Before long the travellers came upon some Yakut tents. There Obruchev learned from a man by the name of Pyotr Sleptsov that the provisions dispatched from Oimyakon to

The Indigirka River

Chibagalakh had been rafted to Tyobyulyakh (250 kilometres down the Indigirka) a month earlier and left there. Tyobyulyakh could be reached from where they were either by boat along the Indigirka or in a roundabout way over a difficult rocky path across the high mountains on the left side of the river.

Sleptsov sold a small boat to the expedition and hired out a larger boat which he brought on a sled drawn by a bull.*

On August 1, the expedition started out on the long journey to Tyobyulyakh. It split up into two parties: Protopopov took the caravan across the deep Elga River and set off over the mountains with Pyotr Sleptsov acting as guide, while Obruchev, Salishchev and a Yakut worker went down the Indigirka on the two boats. Obruchev took the small boat and Salishchev and the worker sailed in the "big" one. But this "big" boat was so small that they had to tie two logs to the sides so that it could hold the two of them. In addition, they towed a collapsible canvas boat into which they had put their instruments, tent and provisions.

* Wheeled vehicles are not used along the Indigirka because of the swamps in that area. The local inhabitants use sleds in both winter and summer to haul hay, firewood, and water.

Ahead of them lay unknown territory. In 1891, Chersky had taken a southern trail over the Verkhoyansk Range to Oimyakon, but the Indigirka remained unvisited. The only information about it was contained in a few lines written by geographer G. Maidel, who had travelled through Yakutia in the second half of the 19th century: "... The left bank is mountainous almost to its confluence with the Selennyakh, while the right bank is flat and marshy." Maps showed the same thing: "... The lowland along the right bank of the Indigirka extended from the north all the way to the Oimyakon depression, while along the left side stretched the wild Kekh-Tas Range, separated from the Indigirka by a small river, the Syuryktakh-Arga" [42].

After passing through a labyrinth of islands lying at the mouth of the Elga, the boats sailed out into a wide river, three to four kilometres across in some places. Despite its width, the river carried the boats at a speed of no less than six kilometres an hour in the slowest parts, and up to 12 kilometres an hour over rapids.

The explorers soon learned how wrong the information they had about this territory was: "At the Nelkan — a river that joins (the Indigirka) below Taryn-Yuryakh — instead of lowland along the right bank there were huge mountains with patches of snow at their summits, which are no less than 2,000 metres high.

"On the next day, the mountains did not get any lower, and a high ridge appeared on the left bank as well. At the mouth of the Nera — a large tributary — black bald mountains appeared on the right, no less than 2,500 metres in height, with a great deal of snow and a network of granite veins sticking out along the crests and peaks like jagged walls, giving the mountains a sombre and fantastic appearance" [43].

Below the Nera, the Indigirka quickly narrows, but its current is even swifter. High cliffs and mountains reaching into the clouds rise up on both sides.

For twelve days the explorers sailed down the rushing river, now reaching speeds of up to 15 kilometres an hour over rapids. It was almost impossible to move close to the cliffs; the water pounded against them with great force. It was a tremendous strain to steer the boat while examining the cliffs, sketching the strata folds, taking pictures and recording observations.

Towards evening on the twelfth day, they reached the mouth of the River Wolchan, at which point they stopped to spend the night. On the next morning Obruchev and Salishchev climbed the nearest steep mountain, from which, according to Maidel's account, they should have been able to see lowlands to the east or north.

"You get a rather extensive view from up high, and it is clear that there are no lowlands or swamps here at all," Obruchev writes. "A few mountain chains, the biggest of which disappears into the clouds south of the Wolchan, intersect the river. All of them run from east to west, across the river, and the Indigirka cuts them along a narrow valley which in places turns into a real gorge" [44]. This was a remarkable discovery in itself, well worth going through all the hardships and privations during the long journey!

Further on, the river became even swifter. The travellers passed several mountain chains as they sailed along winding gorges flanked by sheer walls. But suddenly they spotted two tents, and as they pulled up to the bank, some Yakut women and children came up to meet them. They told the travellers that the man with them, Michika (Dmitri) Starkov, had gone to the executive committee in Oimyakon to find out what to do with the flour he had gotten for the expedition. They knew nothing about the route to Chibagalakh, but said that somewhere down below, at the end of the Tyobyulyakh valley, lived a man by the name of Ivan. "who knows everything".

Obruchev decided to head for the mouth of the river Inyali where the caravan was supposed to come out. That was the point to which all the provisions had to be sent and where they would look for a guide.

The Inyali and the river Yechenka, which flows into the Indigirka directly opposite it, flow through dark, high-sloped valleys, with mountains of over 2,000 metres in elevation rising in the distance. At the upper end of the Yechenka valley a high snow peak could be seen.

After a long search for a guide the party came to an agreement with Michika Starkov, who had arrived by then, that he would lead them to the Chibagalakh through the mountains, since to go on along the Indigirka was no longer possible.

On August 10, Protopopov's caravan reached the mouth of the Inyali. The journey through the many mountain

chains, with their rocky slopes and high passes, and across deep fords and swamps was so difficult that both men and horses arrived completely exhausted. Protopopov had also noted a series of parallel chains extending in a west-northwest direction.

A day later, Obruchev and Protopopov set out downstream to examine the cliffs and to see at least the beginning of the famous Indigirka rapids.

They sailed swiftly down the Indigirka in a small boat with two logs tied to its sides. After going through a narrow gorge they entered a widening of the valley that ran alongside a mountain chain. Further on, the river made a sharp turn, forming a transverse gorge with the main rapids.

Suddenly, they ran into a series of high foamy waves rising up between pebble beds. The boat became filled with water. Obruchev and Protopopov sat waist-deep in water, but the boat did not tip over or sink because the logs held it steady. Rowing with all their might, the men managed to pull up to a cliff, where they examined the rocks, and then, hanging the straps holding their notebooks and cameras around their necks, they again pushed off downstream.

Once again they hit a rough spot and had to pull over to shore to bail the water out of the boat. Further on, they passed the place where the sacks of flour for the expedition were stacked on the bank.

Towards evening, they reached the end of the widened section of the Indigirka valley; ahead of them they could see the beginning of a gorge, with turbulent, foamy water—the famous Indigirka rapids. On the bank appeared the tent of Ivan, "who knows everything". They tied up at that spot and got out. The next day had in store for them a hard journey through the pathless taiga.

They started out at daybreak, but arrived at the expedition's camp only after midnight. Preparations in Tyobyulyakh continued for two more days. Finally, the expedition set out up the Inyali valley, heading due west. The route lay now through pebbly areas, now through expanses of ice sill, now through forests and meadows. The valley slopes were steep and the peaks and crests of the ridges on either side sharp and rocky.

On August 18, they came to the place where a large tributary, the Silyap, joined the Inyali. Beyond it rose the high granite Silyap chain with its snow-covered crest.

Between the Silyap and the Inyali loomed a huge mountain—an isolated summit with a solid snow cap. This was Mt. Chyon, one of the highest peaks in that part of the Chersky Range. Long tongues of snow extended down from the crest of Mt. Chyon into narrow gorges filled with moraine.

At one of the stopping places along the way Salishchev determined Mt. Chyon's height. His estimate was "about 3,100 metres".* "We were delighted," writes Obruchev. "No geographer ever imagined that there were such high mountains in Northern Siberia" [45].

On August 22, the party reached a wide valley with a wonderful meadow, located at the upper reaches of the Inyali. Since they planned to return by the same route, they decided to leave part of their supplies there, as well as the exhausted and limping horses.

Now they faced a difficult rocky upward climb to the pass leading to the basin of the River Myuryule, which interflowed with the Chibagalakh. After that they went along the austere Myuryule gorge. There was no path, and Michika led the caravan by following tracks, but mostly "by inspiration". The river became more and more abounding in water and turbulent. Fording it became increasingly difficult until finally it became altogether impossible, whereupon Michika pointed out a way over the mountains. The caravan reached the pass with difficulty before nightfall. From there, mountain crests could be seen extending to the very horizon, but they were not as high or as snowy as in the mountain chain already traversed.

Later the expedition descended into the Nokyona River valley, overgrown with a sparse larch forest. From the plateau of the Nokyona's right bank they finally saw the Chibagalakh and descended to the tents on its bank. After lengthy questioning about all the tributaries of the Chibagalakh, the travellers set out towards the River Talynya.

Going up the Talynya, the expedition came almost to the end of the forest and stopped on a terrace at the edge of the valley to do some geological prospecting. Obruchev, in the meantime, proceeded over a high mountain chain into the valley of the River Olchan, which flows into the Chimal-

* Salishchev's measurement was shown on maps for a long time, but it was later determined that it was exaggerated. According to current data, Mt. Chyon is 2,681 metres high. A peak to the south of it rises to a height of 2,703 metres.

ga, which, in turn, flows into the Syuryuktyakh. Wrote Obruchev: "So here, finally, I found that mysterious River Syuryuktyakh, shown on all maps as being so long and as flowing all the way from the Verkhoyansk Range to Moma!" Actually it flows latitudinally and not meridionally as had been shown on the maps, and is no bigger than the Chibagalakh.

After completing the geological prospecting on the Olchan, the expedition returned to the Chibagalakh on September 13, and then started on the return journey.

A new guide led the expedition to the Myuryule by another route, bypassing the Nokyona. The weather turned cold; there was deep snow and a snow storm at the pass. Finally, at the upper reaches of the Inyali, the expedition descended into meadows that were not yet covered with snow, and there they found the horses they had left earlier.

The two following days the travellers went along the upper reaches of the Inyali and its right tributary, after which they went through the pass leading into the Elga River basin. They arrived at the mouth of the Elga on October 5, and there they built a winter hut where part of the expedition was to remain for a while. Salishchev took astronomical observations at night. He "doesn't know which to prefer, the mosquitoes that tortured him two months ago, or the minus 30 degree frost ... a difficult ordeal for an observer. You can't touch the screws on the instruments, and the eyepiece gets covered with ice" [46].

From the mouth of the Elga, Obruchev, Salishchev, three Yakut workers and a guide proceeded to Oimyakon, leaving nearly all the supplies in the winter hut. On the very first days of their stay in Oimyakon, the scientists carried out a series of astronomical observations, every night admiring the northern lights.

In the winter, Oimyakon is windless, with little snowfall. Meteorological observations have shown that the winter months in Oimyakon are three to four degrees colder than in Verkhoyansk, which is so famous for its frosts.* At that time, geographers thought that the Earth's pole of cold was located in Siberia. Now, as we shall see in the following chapters, it has moved to the Antarctic.

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* In terms of its relief, the Oimyakon valley is a depression in which cold air accumulates.

Obruchev then made his last trip along the Oimyakon valley to the upper reaches of the Indigirka, during which he took geological observations and made a route survey, all in weather below —40°C.

The part of the expedition that had stayed behind at the mouth of the Elga had in the meantime been sent warm clothing, and on November 21, it too came to Oimyakon by reindeer sledge. Then, on November 28, the entire expedition set out by reindeer sledge on the return journey over the Verkhoyansk Range. The temperature reached —50°C in the daytime and was evidently about —60°C at night. On the evening of December 24, the travellers reached Yakutsk.

* * *

The results yielded by Obruchev's Indigirka expedition of 1926 were of immense scientific value. Apart from providing geological data on previously unexplored regions, the expedition accurately mapped a huge blank-space area on the basis of eight astronomical points.* This work laid the basis for correctly mapping a vast area in Northeastern Siberia about which geographers had previously held erroneous notions.

The most important result, however, was the great geographical discovery made.

Moving down the Indigirka River from the mouth of the Elga, the expedition found several high rocky mountain chains stretching longitudinally in an area where, according to G. Maidel's report, based on information gleaned from local inhabitants during his 1868-1870 travels, there was supposed to be a lowland.

Comparing his observations with the geological structure of the area, and then with the observations made by Chersky, who had also come across several high mountain ranges on his way from Oimyakon to Verkhnekolymsk, Obruchev concluded that the expedition had discovered an enor-

* The map was a supplement to the expedition's report. It was made by K. A. Salishchev on the basis of route surveys and astronomical points. All the technical and scientific workers in the expedition took part in making route and exploratory surveys in various areas. In addition to the eight astronomical points determined by Salishchev, use was also made of another point, one that had been established before the revolution, at the mouth of the Amga River in the lower reaches of the Aldan.

mous mountain range extending through the entire territory.

All in all, nine latitudinal mountain chains had now been crossed in the newly discovered mountain system. The southern chains rose to altitudes of 2,000 to 2,200 metres, and the northern ones to over 2,500 metres.

After Obruchev's report on the expedition, the Geographical Society of the USSR decided in 1927 to consider the newly discovered range to be an independent geographical unit and to name it the Chersky Range.

S. V. Obruchev

I. D. Chersky had not only explored areas near those where Obruchev's expedition worked, but in the course of his explorations he had noted the main feature in the arrangement of the mountain ranges in the Kolyma-Indigirka area: "Due to the marked differentiation with the Indigirka-Kolyma mountain mass, the north-westerly or north-north-westerly direction followed by the chains forming it is clearly observable, that is, a direction almost perpendicular to the two main rivers mentioned above" [47] (the Kolyma and the Indigirka), whereas, judging by the way the deep valleys of these two rivers ran, it would be natural to assume that the mountains stretched in a northeasterly direction, and that was the way they appeared on old maps. Therefore, there was every justification for naming the newly-discovered mountain system after Chersky.

As for the Kekh-Taz Range, mentioned by G. Maidel, which allegedly extended meridionally along the left bank of the Indigirka, the expedition established that no such range existed. In fact, the local inhabitants had never even heard of the name, Kekh-Taz (Blue Mountains).

Obruchev's expedition also determined the arrangement of the mountain chains within the Verkhoyansk Range. Crossing it, the expedition saw that its structure was more complex than had been previously thought; there were actually four chains rather than one as had been expected. Obruchev gave names to all four, as well as to some chains within the Chersky Range.*

* * *

Busy exploring a totally unknown area in the Indigirka River basin and discovering a whole mountain system, the Chersky Range (the Chersky Elevation), S. V. Obruchev was unable, in 1926, to study the eastern part of the Kolyma-Indigirka area. In 1929-1930, however, with the help of the Yakut Commission of the USSR Academy of Sciences, Obruchev organised a new expedition to the Kolyma area, this time with the aim of exploring the still unknown eastern half of the Chersky Range, making an accurate map of the vast Kolyma River basin, and studying its geological structure.

The Kolyma-Indigirka area was subsequently visited by a number of other expeditions, whose work, together with the work done by Obruchev's expeditions, provided a scientifically sound basis for planning the economic development of that outlying region of the USSR. Significant changes appeared in the geographical map of the Kolyma basin. Suffice it to say that not only did the size and contours of the Kolyma's tributaries change, but the Kolyma itself (a river over 2,000 km long) "shifted" 200 km to the south-east in its upper reaches, whereas in its lower reaches it "moved" to the north-west. The Korkodon River, a large right tributary of the Kolyma, shifted 200 to 250 km to the north-east. The picture of the structure and arrangement of the mountain ranges, uplands and lowlands also changed. It was learned, for example, that the Taz-Kystabyt Range, which had previously been thought to stretch latitudinally, actually curved southward, as did the eastern part of the Chersky Range. "Rivers and mountain ranges were finally shifted on the map to the places where they belonged" [48].

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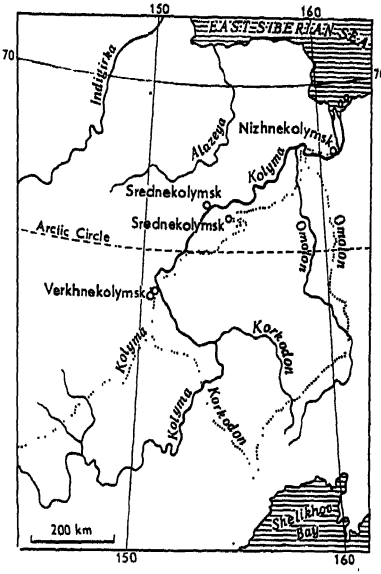
* On some recent maps, this mountain system is called the Chersky Elevation.

Accompanying Obruchev in the 1929-1930 expedition were geodesist K. A. Salishchev, radio operator V. Bizyayev and a number of workmen.

Making for the Kolyma, the travellers took the winter route from Yakutsk to Oimyakon. They made use of draught oxen to get from Krest-Khaldzhai to the mouth of the East Khandyga River, where they changed over to reindeer sledges. The 1926 expedition had passed through this region in the severest of frosts, but now it was April and the still icebound river and the slopes of the Verkhoyansk Range sparkled in the bright sunshine.



Sketch of the Kolyma river and some of its tributaries as shown on old and present maps

Dotted lines indicate river system as shown on the 1916 map

Their way lay along the river. The snow was melting, so the sledges had to be pulled through slush and water. The closer they came to the Verkhoyansk Range, the more water there was. The greater part of the time was spent in dragging the sledges out of the slush and searching for ways of getting through dangerous places.

On May 4, after having crossed the Verkhoyansk Range over the same route taken by the 1926 expedition on its return trip, our travellers reached Oimyakon. They travelled the rest of the way to the upper reaches of the Kolyma on horseback.

Upon reaching the Ayan-Yuryakh, a left tributary of the Kolyma, the expedition broke up into two groups. Both groups headed downstream, one, led by Salishchev, going along the left bank, and the other — Obruchev, a workman and a guide — by water, the guide in his own native boat, Obruchev and the workman in a folding canoe made of rubberised cloth. The guide, an old Yakut, supplied Obruchev with the names of all the rivers and valleys they passed.

On June 20, they reached the settlement of Orotuk, the centre of the upper Kolyma area. Below Orotuk the Kolyma enters a winding gorge cutting through the southern end of the Chersky Range, which runs parallel to the Verkhoyansk Range and breaks up into a number of short ridges.

The gorge, with huge granite boulders on either side, ends near the mouth of the Tyanka River, a right tributary of the Kolyma.

Below the mouth of the Tyanka, the Kolyma again cuts into granite mountains. The peaks of the most beautiful ridge (the Bolshoi Angachik) rise as high as 2,500 m. From there the Kolyma flows through sombre gorges all the way to where the rapids begin.

All in all, the Kolyma has five rapids, with several smaller rapids between them. They are all found on a strip of the river not more than 10 kilometres long. Obruchev and his companions had great difficulty in getting over the rapids.

The two groups met, as had been planned, at the mouth of the Taskan River. They camped there for three weeks, during which time they built a boat large enough to carry the whole expedition on further.

Between the Taskan and Seimchan, the Kolyma cuts through the easternmost chains of the Chersky Range.

A few days' journey brought the expedition to Srednikan. They had been travelling through virtually uninhabited territory, covering hundreds of kilometres without meeting a single human being. Nowadays, however, this is a lively industrial region with a large population.

With the Chersky Range now behind them, the travellers were soon at the Kolyma's middle reaches, which begin at the mouth of the river Buyunda, a right tributary of the Kolyma. As they moved on, the valley grew wider, and the river split up into numerous channels. The travellers stopped at Seimchan, where they made improvements on the boat by making a canvas hood for it and putting up a mast.

From Seimchan, the Kolyma flows north for hundreds of kilometres through a narrow valley in the northeastern foothills of the Chersky Range. But at Mt. Shapka it turns to the north-east, cutting into the edge of a plateau. The river becomes wider and wider, and in it numerous islands covered with larch and poplar appear.

Below the mouth of the Korkodon, the Kolyma turns to the north-west and cuts through a ridge of ancient rock. Here the Kolyma flows into the Upper Kolyma Depression, the southernmost part of the Kolyma Lowland which extends to the north as far as the sea. "To the west of the Upper Kolyma Depression," Obruchev wrote, "one can see the easternmost chains of the Chersky Range, while to the east and north only the wavy surface of a plateau that extends as far as the Omolon River. We called it the Yukagir Plateau" [49]. This name now appears on all geographical maps of the region.

Passing through the Prorva channel, the expedition entered the Yasachnaya River, a tributary of the Kolyma, and landed at Verkhnekolymsk, where the explorers visited the house in which Chersky had spent his last winter.

The lower reaches of the Kolyma begin at Verkhnekolymsk. Here the Kolyma has a slow current, a wide bed and very few islands.

Eight days later, on September 1, the travellers reached Srednekolymsk, where they bought a boat in which, on September 6, Obruchev and two other men started for the mouth of the River Omolon. The rest of the party remained at Srednekolymsk where the whole expedition was to spend the winter.

After Obruchev and his companions passed the Konzoboi, the last cliff on the right bank of the Kolyma, the river had low banks all the way to Nizhnekolymsk. The first snow had already fallen, little snowdrifts appeared, and the migration of birds to the south had begun.

On September 20, Obruchev's party started back in a motor boat. They spent the first night of the return trip in the isolated village of Gornitsa where, on June 24, 1892, Chersky had spent his last night.

On September 29, they reached Srednekolymsk. A few days later, the river froze over, cutting the town off from the rest of the world. In mid-December, a twenty-day polar night set in. The expedition stayed there until the middle of February.

On February 12, the expedition began its journey in reindeer sledges, first travelling up the Kolyma, and then turning into the Korkodon valley, along which they proceeded in an easterly direction. As they moved eastward, that

is, towards the sea, the snow became deeper and deeper, making it harder and harder to travel and to find food for the reindeer.

The valley of the upper Korkodon stretched southward, so to proceed eastward, the travellers turned from the valley and went up the Russkaya Rechka River. They moved deeper and deeper into a chain of high mountains.

The wide glacial valley of the Russkaya Rechka gradually passed into the valley of another river of the same name, but belonging to the Omolon River basin. Upon reaching the Omolon itself, the travellers followed it and, finding timber good enough for building a large boat, they camped at the foot of the cliffs on its bank.

Climbing the nearby mountains, the explorers saw in the east a number of mountain chains skirting the coast of the Sea of Okhotsk. "These chains formed a part of the range designated on old maps as the Kolyma Range, but called 'Gyda' (meaning 'marine') by local Tunguses and Yakuts. The name Gyda is also mentioned by Chikhachev, who had gathered information about the upper Kolyma area when he was on the coast of the Sea of Okhotsk as far back as the middle of the last century" [50].*

Spring came at last. The snow began to melt, and the ice on the Omolon broke. On June 9, the expedition started down the now overflowing Omolon. "The Omolon is one of the most desolate rivers in the area. Going up the Omolon to Gizhiga is a difficult undertaking; the local inhabitants almost never go further than Oloi.... Sixty years ago [these lines were written in 1930 — *N. G.*], a topographer from Maidel's expedition sailed the Omolon from the mouth of the Kegal and made a very rough survey of the river" [51].

Sailing down the rapid and overflowing river involved many hardships and dangers. There were vast marshes at

* After Obruchev's expedition, the name, Gyda, appeared on geographic maps, but later the range was again designated as the Kolyma Range. On some recent maps, the range carries no name at all, for the latest explorations have found that it consists of a number of isolated massifs standing on a flat upland area broken up by river valleys. Nevertheless, a name for the whole system of elevations separating the Kolyma River basin from the Sea of Okhotsk (and partly from the Bering Sea) is absolutely necessary. The Kolyma Mountains might be a suitable name. The lack of a name for the huge mountain area on recent maps is a serious shortcoming. This mountainous region has come to be called the Kolyma Upland.

the foot of the mountains on both sides of the Omolon, and now that it was warmer, swarms of mosquitoes harassed the travellers.

Along both the Omolon and the Korkodon, the expedition established several astronomical points.

On June 12, the travellers reached the Kolyma where they ran into a strong headwind blowing from its lower reaches. While waiting for it to subside, Obruchev paid a visit to Chersky's grave near a small chapel in the village of Kolymskaya.

Twenty hours after resuming the journey from the mouth of the Omolon the explorers arrived at Nizhnekolymsk. They stayed there until August 18, then boarded the steamer *Kolyma* and were on their way to Vladivostok.

The 1929-1930 expedition found that the eastern end of the Chersky Range ran not north-east as Obruchev had supposed in 1926, but south towards the Sea of Okhotsk.

Obruchev's new conclusion was that "... the main ranges — the Verkhoyansk and Chersky ranges — stretch parallel to each other in a curve resembling the letter S. The Verkhoyansk Range runs along the Lena and Aldan rivers and passes in the south into the Dzhugdzhur Range, which skirts part of the western coast of the Sea of Okhotsk. The curve ends here, whereas the more southerly so-called Stanovoi Range constitutes another mountain system.

"The curve of the Chersky Range is parallel to that of the Verkhoyansk Range. Beginning near the Arctic Ocean, where it is known as the Taz-Khayakhtakh Range, it runs southward, then turns east and, crossing the Indigirka, continues in this direction as far as the Kolyma, from which it runs almost meridionally again, crosses the Okhotsk watershed and comes to an end, covered with late deposits, without reaching the sea. This enormous mountain curve is cut off by the depression of the Sea of Okhotsk..." [52].

Between the Chersky and Verkhoyansk ranges lies a vast plateau, which in the south is split in two by the Taz-Kystabyt Range. The eastern part is called the Nersk Plateau; the western is the Oimyakon Plateau, with the Oimyakon Depression in the middle. The Taz-Kystabyt Range runs "parallel to its elder brothers", the Verkhoyansk and Chersky ranges. The three ranges and the plateaus separating them end near the coast of the Sea of Okhotsk. Their ends and sides form

the Indigirka-Okhotsk and the Kolyma-Okhotsk watersheds.*

"Consequently, the former Kolyma Range, which was supposed to stretch eastward in a continuous chain from the upper Okhota along the coast of the Sea of Okhotsk, is actually broken up into a number of portions differing both in origin and relief, namely, two plateaus and two ranges stretching almost meridionally and crossing the Okhotsk watershed. In the east, less than half of that Kolyma Range remains, and only that part is apparently homogeneous in its structure and forms and can be called a range. But with its dimensions thus altered, the range should also receive a new name, all the more so since the local inhabitants have long called it by a different name — the Gyda (marine) Range — a name even mentioned in the geographical literature, whereas no one in the area has ever heard of the Kolyma Range.** The Gyda Range runs north to merge with ... the Anadyr Range***" [53]. The latter was sketched by S. V. Obruchev in 1933 (see Chapter 6).

North of the huge Chersky and Kolyma (or Gyda) ranges which engirdle the Kolyma River basin lie two plateaus. One of these, named the Yukagir Plateau by S. V. Obruchev, is situated between the Omolon and Kolyma rivers; the other, which K. A. Salishchev suggested calling the Alazeya Plateau, lies between lower reaches of the Kolyma and Indigirka rivers. The Alazeya Plateau is separated from the Chersky Range by the wide valley of the Ozhogina River. Along the left bank of both the Indigirka and Kolyma rivers are vast lowlands stretching all the way to the East Siberian Sea.

Such, in general outline, is the arrangement of mountain ranges, elevations and lowlands in the Kolyma-Indigirka region.

Life in that area has greatly changed since the years of exploration described above. Even in the most remote places where in Obruchev's time one would find only solitary tents

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* In the region where the Verkhoyansk Range approaches the Dzhugdzhur Range, part of the former's system was later singled out as the Suntar-Khayata Range.

** See note on p. 96.

*** Later, S. V. Obruchev began to refer to the Anadyr Range as the Chukotsky Range, as suggested by Academician V. A. Obruchev back in 1924. At present, it is called the Chukotsk Upland.

here and there, the Yukagirs and Evens live in houses equipped with electricity. The mining industry, working the rich mineral deposits, is developing rapidly. Agriculture, too, has completely changed. The collective farms have their own agronomists and livestock experts; the latest agricultural machinery; clean, spacious stalls for high-grade cattle, such as had never before been seen in the area; experimental fields and gardens, and veterinary stations. Everywhere there are schools, kindergartens, libraries and hospitals.

This outlying part of Asia, which before the revolution had been in the position of a remote and backward colony, now lives a full and vigorous life along with the rest of the country.

CHAPTER 6

NEW EXPLORATIONS OF THE INDIGIRKA RIVER BASIN. ALTERATIONS IN THE MAP OF THE EXTREME NORTH-EAST OF ASIA

Air photography has led to the discovery of new areas of recent glaciation in Siberia, specifically, in the Suntar-Khayata Range, in the Buordakh Massif (the central part of the Chersky Range) and in the Koryak Range, that is, in places where the existence of glaciers was thought to be improbable due to the dry climate.

S. V. Kalesnik

S. V. Obruchev's 1926 and 1929-1930 expeditions were not able to solve all of the riddles of the Kolyma-Indigirka area. Later, some amazing, unexpected and highly important new discoveries were made there. In a part of the world in which recent glaciation had been virtually unknown and where even the very existence of large glaciers had been deemed impossible by most geographers, vast mountain-glacier regions were found.

The largest glaciers were discovered in the mountains forming the watershed between the upper Indigirka, the upper Yudoma (the Aldan River basin), and the upper Okhota (the Sea of Okhotsk basin). This mountain mass is now singled out on maps as the Suntar-Khayata Range.

The Suntar-Khayata Range is 150 km long and 40 to 50 km wide. It rises to an elevation of nearly 3,000 m above sea level (the highest point in it is the 2,959 metre-high Mt. Mus-Khaya), which is higher than Mt. Chyon in the Chersky Range, a mountain long considered to be the highest in northeast Asia.*

The Suntar-Khayata Range, with its steep slopes and jagged rock formations, stands out noticeably among the

* It is now known that Mt. Mus-Khaya is actually second in height to Mt. Pobeda (3,147 m) in the Buordakh Massif of the Chersky Range.

An aerial photograph of a glacier in the northern part of the Suntar-Khayata Range.

neighbouring mountain chains because of its singular height. Crowning the range is a sharp peak with five glaciers creeping down its slopes in different directions.

From time to time between 1939 and 1945, geologists working in the region reported the existence of glaciers there, but their fragmentary information gave no idea of the extent of glaciation in the Suntar-Khayata Range. This became clear only after the Aerogeodetic Administration provided photographs of the area (1944-1946). Photographs taken from the air and ground observations by a team of geographers made it possible to complete a thorough study of the newly-discovered glacial region in a very short period of time.

The expeditionary party which had set out to explore the glaciers by land came across visual evidence of the existence of glaciers even before reaching or seeing the glaciers themselves.

The days were hot and cloudless; it had not rained for a long time. The ground began to show cracks here and there; the rivers shallowed, baring numerous shoals; and the smaller streams and marshes were gradually drying out. On the other hand, the rivers coming down from the Suntar-Khayata Range had begun to rise rapidly as soon as the hot weather set in. Their current became swift and the water muddy. Finally, the rivers overflowed their banks. On one river, the water swept away a bridge and flooded a village situated on its bank. The only thing that could cause that kind of summer flooding would be the intensive melting of glaciers.

At last, the party reached the first glacier. Its terminus was a sheer, ten-metre-high precipice of pale blue ice containing thin layers of earth and rock particles.

Day after day, the men went deeper into the mountains, where, with the help of the aerial photographs, they located and explored new glaciers. "At the source of nearly every stream, in huge cirques cutting into the mountain slopes, there is one, sometimes two or three, glaciers" [54].

A total of 208 glaciers, ranging in shape and size from small névé basins and kara glaciers* to valley glaciers as much as eight kilometres in length, have been discovered in the Suntar-Khayata Range. Some of these have been named after Soviet geographers. For instance, one of the larger glaciers in the northern part of the range was named after A. A. Borzov, a well-known Soviet geographer, Moscow University professor and founder of a new school of Soviet geography. The area of glaciation in the Suntar-Khayata Range is 246 sq km.

Another glacier region in Northeastern Siberia that was discovered with the help of aerial photography was the Buordakh Massif, 500 km to the north of the Suntar-Khayata Range in the Indigirka River basin at the watershed between the Buordakh and Tirekhtyakh rivers, left tributaries of the Moma River. This high massif, which is part of the Chersky Range, has the highest mountain in the range and in all of North-East Asia — Mt. Pobeda (3,147 m).

* A kara glacier is one found in a kara, a cirque in the upper slopes of a mountain.

The first data on the glaciers in the Buordakh Massif were provided in 1940 by I. E. Isakov. He saw the ends of tongue-shaped glaciers on the southwestern and northeastern slopes of the massif. Unfavourable weather and the inaccessibility (without special equipment) of the slopes with their jagged alpine relief forms, prevented Isakov from exploring the glacier region he had discovered. He had to confine himself to examining the tip of one of the glaciers on the western slope of the massif and observing from a distance glaciers at the upper reaches of the two rivers on the eastern slope. He could not even estimate the size of the glaciers.

Subsequently, again with the help of air photography, a large number of glaciers were discovered there and their size, nature and arrangement determined. In area of glaciation and in number of glaciers, the Buordakh Massif ranks far below the Suntar-Khayata Range*, but "in the classical form of its glaciers, which descend far down along the valleys ... or in the compact arrangement of its glaciers, it does not yield to the Suntar" [55]. The glaciers of the Buordakh Massif reach eight kilometres in length.**

The Buordakh Massif is cut off from the north by the wide swampy valley of the Moma River, forming in this place the famous Moma ice body, with an area of 60 sq km. In 1945, an extinct volcano with an execellently preserved crater was discovered on the right bank of the Moma. The crater, it turned out, contained a lake with pieces of volcanic pumice floating in it.

Besides the Suntar-Khayata Range and the Buordakh Massif, glaciation was discovered also in a good number of mountainous regions of the Chersky Range and Indigirka-Okhotsk watershed system.*** More than 50 glaciers have

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* The Buordakh Massif has fewer than 100 glaciers, and the area of glaciation is 95 sq km.

** A. P. Vaskovsky [56] figures that no glacier in the northeastern part of the USSR exceeds 7.8 km in length, that is, 8 km, in round figures (this also applies to the Suntar-Khayata Range described above).

*** In the Myuryule region in the Chersky Range at the upper reaches of the Myuryule River, and also east of the Suntar-Khayata Range in the high-mountain sector of the Indigirka-Okhotsk watershed, at the upper reaches of the Kukhtui and Kuidusun rivers. A small group of glaciers is located on Mt. Chyon in the Chersky Range. During his 1926 expedition, Obruchev noted the existence of an ice tongue and possibly a glacier at the summit of Mt. Chyon. Later, geologist A. P. Vaskovsky took pictures of the Mt. Chyon glaciers. Glaciation was also found in the high Silyap Massif south of Mt. Chyon.

been found in the Orulgan chain of the Verkhoyansk Range system. The total number of glaciers discovered in the Indigirka basin and the adjacent mountain regions of Northeastern Siberia exceeds 450. In a number of glaciers and the area of glaciation* this mountain-glacier region ranks fifth in the USSR after the high-mountain regions of Central Asia, the Caucasus, the Koryak-Kamchatka area and the Altai.

* * *

Pre-revolutionary maps of Eastern Siberia showed, very schematically, a huge mountain chain extending from the Baikal region to the Chukotka Peninsula; it was called the Yablonovoi or Stanovoi range. Today, the name Yablonovoi Range applies to one of the Transbaikal chains extending north-east only to the Olekma River. The Stanovoi Range stretches from the Olekma in a latitudinal direction to the Sea of Okhotsk. Further along what was formerly called the Yablonovoi, or Stanovoi, range, today's maps distinguish the Dzhugdzhur Range,** the Suntar-Khayata Range (cutting across the whole area), the Kolyma (Gyda) Range, the Anadyr Plateau and the Chukotka Elevation. East of the Kolyma Range, the Koryak Elevation stands apart as an extension of the mountains of Kamchatka but separated from them by a lowland area.

Academician V. A. Obruchev played a big role in working out this new picture, much more accurately reflecting the relief features of the eastern sector of the Asiatic part of the USSR. He analysed a great volume of material derived from explorations of the Transbaikal area and the Far East

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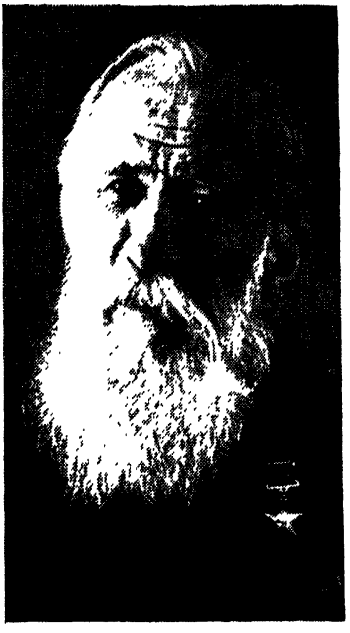
* L. L. Berman estimated the total area of glaciation in the open mountain-glacier region to be 588.8 sq km, of which 358.9 are in the Suntar-Khayata Range and 205 in the Buordakh Massif. Y. N. Popov pointed out in 1948, however, that according to more precise data, the area of glaciation in the Suntar-Khayata Range does not exceed 160 sq km, and he estimated the glacier area of the Buordakh Massif to be 93-94 sq km. The total area of glaciation, in his opinion, is only a little over 250 sq km. According to data gathered by A. P. Vaskovsky, there are 467 glaciers, with a total area of 409 sq km, in the various regions of Northeastern Siberia (excluding the Pacific coast sectors of the far north-east of the USSR).

** The Dzhugdzhur Range had figured on earlier maps, but only in the latitudinal segment of the Aldan-Okhotsk watershed that adjoins the Skalisty Golets from the east.

and made a precise outline of the Yablonovoi and Stanovoi ranges, showing their boundaries as they are presently known. He was the first to point out that the Kolyma Range cannot be considered to be a continuation of the Stanovoi Range [57].



V. A. Obruchev

Important geographical explorations have been carried out in Soviet times of all the above-mentioned ranges and elevations, especially of the mountain regions in the far north-east of Asia that had virtually never been explored before. Substantial results were obtained by S. V. Obruchev's 1929-1930 expedition which explored the region neighbouring the Kolyma basin. And we have already mentioned the discoveries of glaciers in the Suntar-Khayata Range and in the Kukhtui region. Relatively large recent glaciers were also discovered in the summer of 1937 in the internal regions of the Koryak Elevation.

A. P. Vaskovsky's data indicate that there are 461 glaciers in the Koryak Elevation, and the area of glaciation is 185 sq km.* However, studies made by N. M. Svatkov during the IGY showed the area of glaciation to be 205 sq km.

The Koryak Elevation was first differentiated out as the Koryak Range by S. V. Obruchev and K. A. Salishchev during the 1932-1933 Chukotka air expedition of the Arctic Institute, one of the first Soviet geographical

* Unlike A. P. Vaskovsky, we do not incorporate these data into the data on glaciation in Northeastern Siberia because the conditions for glacier formations here, in the Pacific coast region, are substantially different. They more properly belong with data on glaciation on the Kamchatka Peninsula.

expeditions to use an airplane for explorations and mapping.

During Obruchev's 1926 and 1929-1930 expeditions, discussed in the previous chapter, a large part of northeastern Asia was explored in general outline, but vast areas still remained completely unexplored. This applied especially to the Chukotsk National Area and the northern part of the Koryak National Area lying at the extreme northeastern part of the USSR. Yet, "only after studying this tip of Asia—a 'tip' with an area of 700,000 sq km—was it possible to build, on anything approaching a solid foundation, a theory about the geological connection between the Asian and American continents, about the direction of structural lines*, about the curvature of the Pacific arcs, about the distribution of mineral deposit regions..." [58]. Exploration of this "tip" of Asia was made possible with the help of the airplane.

In 1932, flights were made primarily along the coastline of northeastern Asia, across the Chukotka Peninsula and the area north of the settlement of Anadyr, beyond the Zolotoi Range and further west. On the basis of the 1932 surveys, Salishchev drew up a map of the eastern part of the Chukotsk area, which substantially changed the then existing picture of that area and was very useful during the flights made the following year.

In 1933, radial flights in the internal part of the area were made from a number of points. Visual route surveys were made from the air, consisting of sketches of strips up to 50 km wide along the line of flight. The sketches were based on the precisely chartered flight routes. It was determined that the method of "visual route surveys" from the air, suggested by Salishchev and Obruchev, yielded even more accurate results than anticipated.

That year an area of about 375,000 sq km in the Anadyr basin was surveyed for a relatively detailed map. In addition, the northern part of the Chukotka Elevation was surveyed for a smaller scaled map. Geographic and geological observations were also taken from the air.

There were flights during which new geographic discoveries were made almost every minute. Take, for example, the

* That is, about the direction of the axes of structures formed by layers of rock.

radial flight from Anadyr to the Gulf of Krest, described by Obruchev. "A turn to the north-east and before us in the distance we see the Gulf of Krest. Below are large coastal swamps and among them a lake into which flows a lazy, winding river; the lake is connected with the sea by a channel—also a river, but of extraordinary width. None of this is shown on any map—and the Zolotoi Range itself suddenly breaks up before our eyes into two small mountain groups."

The explorations not only added new details to the map, but in some instances removed some. It was once thought that the highest point in northeastern Asia was Mt. Matachingai, "with an elevation of about 1,312 *sazhen* (2,799 m)", at the upper end of the Gulf of Krest. Some geographers had surmised that this was a knot of Chukotka ranges and even of the Kamchatka and Stanovoi ranges; others thought it was an extinct volcano. But no summit of this height was seen at all during the flights.

In a huge snow drift hanging on the slopes of one of the mountains in this region, the explorers noticed two blue spots. This was a hanging glacier, "the first in northeastern Asia".

In the final part of his book about the air expedition [59], S. V. Obruchev draws a picture of the relationships between the Kamchatka-Koryak and the Okhotsk-Chaunsky folded mountain arcs, with the ancient Chukotsky Massif, the basis of the Chukotka Elevation, wedged between them.

Air studies were made of the Rarytkin and Pekulnei ranges, which, like the Penzhinsky Range, found their place on the structural diagram of the terrain of northeastern Asia. Instead of the assumed mountain knot at the juncture of the Chukotka Elevation and the Kolyma Range, there was found a vast plateau completely covered with lava. It was named the Anadyr Plateau. The flights revealed the general picture of the arrangement of the mountain ranges in this area and its connection with geological structure. Subsequent explorations added to and filled in the details of this picture.

Of great significance was the exploration of the northeastern section of the USSR carried out over a period of many years by geographer D. M. Kolosov, who explored the western sector of the Verkhoyansk mountain system and the Koryak Elevation and summarised all the material

on the relief and ancient glaciation of the northeastern part of the USSR from the Verkhoyansk Range to the northeastern extremity of Asia.

The year 1956 saw the publication of a book on the topographical relief of northeastern Asia written by A. P. Vaskovsky. The book, entitled *A Survey of the Mountain Structures of Extreme Northeastern Asia*, provided a new orographical scheme, that is, it broke down the territory into mountains and flatlands, mountainous regions (elevations), mountain arcs, systems, chains, ranges, massifs, depressions, etc.

Thus, as a result of extensive Soviet exploration, a new conception of the geography of the most remote region of our country was formed.

CHAPTER 7

CHANGES IN THE MAP OF OTHER PARTS OF SIBERIA AND THE FAR EAST

Significant advances, a large contribution to world physical geography, have been made in the study of the natural conditions and natural resources of Siberia and the Far East.

V. B. Sochava

Some very important geographical explorations have been conducted on the Kamchatka Peninsula, with its eastern area, famous for its volcanoes, having been subjected to particularly detailed study.

Soviet volcanologists have displayed genuine heroism in their exploration of the Kamchatka volcanoes. For example, V. F. Popkov and I. Z. Ivanov, members of a volcanic station team, once "sailed" on a lava stream flowing down the slopes of the Kluchevskaya Sopka volcano. Jumping onto the crust of the flowing stream and moving along with the lava, they took scientific observations. The temperature of the not yet completely hardened surface of the crust was 270° to 300°C, while at a depth of only 40 cm, was lava with a temperature of 870°C. Bubbles of water vapour, hydrogen chloride and other gases were continuously bursting on the crust. The researchers floated a distance of over two kilometres in a matter of an hour, after which they got off safely onto another stream that had already cooled.

In 1931, the first Soviet ascent of the Kluchevskaya Sopka (4,750 m) was made, and in 1935, two bold explorers—a topographer and an alpinist—descended into the volcano's crater in which recurrent explosions occurred every five minutes. "Dark grey smoke clouded the crater every minute. The pungent odour of sulfurous gas and hydrochloric acid tickled the nose and throat." With each explosion clouds of some-

times dark and sometimes white smoke would pour out. "Clouds of ashes and rocks, many of which were bright red, gushed out to a height of 200 to 300 metres and then fell back down again with a thundering roar." During one particularly powerful explosion, a gigantic cloud poured out and a hail of redhot rocks spilled out onto the bowl of the crater [60].

In 1941, geysers were discovered south of Lake Kronotsky. With a thundering roar, the Velikan (Giant) Geyser emits a column of hot water (95-97°C) and steam every three hours. The fountain of water, which lasts for several minutes each time, rises to a height of up to 30 m, and the steam goes as high as 300 m. All in all, over 20 large active geysers were found, primarily in the Geyzernaya River valley. This was an important geographical discovery, for it is the fourth largest geyser region in the world! (The other regions, known earlier, are in Iceland, New Zealand and the Yellowstone National Park in the United States.)

Intensive volcanic and geographic exploration on the Kamchatka Peninsula also went on in the post-war years. The extent of recent glaciation on the peninsula has been determined: the total area of its glaciers is 866 sq km.

After the Kuril Islands were returned to the Soviet Union in 1945, many Soviet explorers visited them to make a comprehensive study of their natural and geographical features. In 1946, a fundamental revision of the orographic map of Sakhalin and Kuril was made. A number of volcanoes (the Berg, Yermak, Neozhidanny, and others), missing from Japanese maps of that time, were discovered. In a number of cases, Russian names of geographical objects were reinstated on the map of the islands, and many objects that did not have deep-rooted local names — volcanoes, mountains, ranges, passes, rivers, capes, bays and even whole islands— were named in honour of famous Russian and Soviet travellers, explorers and geographers. The map of Southern Sakhalin underwent similar changes. Moreover, the Yuzhno-Kamyshevy Range and many other geographical objects there were differentiated for the first time as separate orographic units. After repeated measurements, the height of Mt. Nevelsky, formerly shown on the map as approximately 2,000 m high and the highest point on Sakhalin Island, was fixed at 1,398 m, making it the second highest after Mt. Lopatin (1,609 m).

The Geyzernaya River valley

One of the first explorers of what is now the Maritime Territory (Primorsky Krai) was the traveller, geographer and writer V. K. Arsenyev, who began his travels in the Far East before the revolution, but whose main works were written and published in Soviet times. In the 1920s he also continued the expeditionary exploration of the Far East.

He described his journey across the Sikhote-Alin mountain range in 1927, in a book entitled *Through the Taiga*. Arsenyev's books, giving colourful descriptions

V. I. Arsenyev

of the Ussuri region and the Sikhote-Alin, are widely read, but perhaps not everyone knows that the honour of discovering many passes and peaks in the Sikhote-Alin Range belongs to him; that he was the first to note the steepness of the eastern, and the relatively smaller inclination of the western, slopes of the mountain system; or that he determined an important biogeographic boundary line indicating the limit of the distribution of Okhotsk and Manchurian flora and fauna. Many other Soviet expeditions have studied the natural features of the Maritime Territory, providing additional information about this distinctive region, so rich in natural resources. Northern Sakhalin and the Shantarskiye Islands have also been studied. The highest point in the Sikhote-Alin Range, long disputed, has been finally determined as being Tardoki-Yan Peak (2,077 m).

The topography of the Amur region has also been clarified and accurately reflected on the map. The Dzhagdy Range, for example, is now shown properly as a continuation of the Tukuringra Range. Geodetic and aerophotographic work carried out in 1936-1937 in the area around the city of Komsomolsk provided a clear outline of the mountains along the left bank of the Amur, establishing the fact that they are not only as high as, but in large part even higher than, the neighbouring Bureinsky Range. Mt. Kharpi in the Dzhaki-Unakhta-Yakbiyana Range has an absolute elevation of over 1,682 m, and the Myao-Chan Range exceeds 1,566 m in height. The more westerly Badzhalsky Range reaches a height of over 2,600 m, exceeding the northern and highest part of the Bureinsky Range.

Parallel with the aerial photography being carried out during these investigations, teams of geodesists, topographers and geographers worked on the ground.

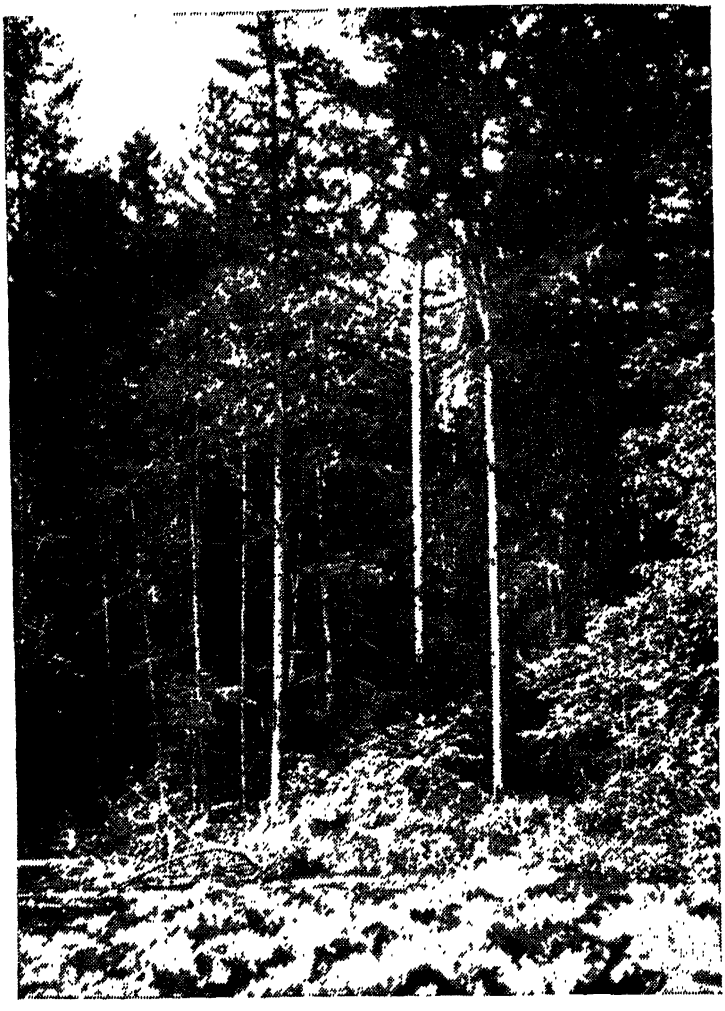
The author of this book had occasion to take a direct part in this work as the head of one of the teams of geographers. We covered many kilometres, by pack horse, on foot and by boat, through the remote and distinctive taiga of the Amur region. Its distinctiveness consists in its natural combination (in accordance with the relief breakdown and elevations) of tracts of austere northern Okhotsk taiga and lush wide-leaf coniferous forests of the Manchurian type.

Soviet explorations introduced substantial changes to the map of Transbaikal area. Besides the work done by V. A. Obruchev in determining the precise boundaries of the Yablonovoi Range (see Chapter 6), many other interesting facts have been revealed. Sokhondo Golets, for example, with a height mark of 2,482 m (2,499 m according to the latest data), is no longer considered the highest point, but rather the mountain, Burun-Shibertuy, with a height of 2,523 m.

The mountains in northern Transbaikal area turned out to be much higher than previously thought. It was found, for example, that the Barguzin Range rises 2,840 m above sea level and is one of the highest and most inaccessible ranges in the Transbaikal area. It has sharp relief forms, characteristic of high mountain regions that had been subjected to glaciation in the past. The Ikatsky Range, which skirts the Barguzin hollow on the east, also turned out to be 400 m higher than previously estimated.

A great deal of light was thrown on the specific features of the Transbaikal area's relief structure by the works of V. A. Obruchev, N. V. Dumitrashko, N. A. Florensov, S. S. Voskresensky, Y. G. Simonov and other explorers.

Much new information about the geography of the Transbaikal area, including data on its orography, was provided by the comprehensive physiographic explorations carried out by V. S. Preobrazhensky and his co-workers in the 1950s and 1960s. Work in the northern part of the Transbaikal area (in the region of the Stanovoi Elevation) led to an important geographical discovery: a mountain-glacier area in the Kodar Range (2,999 m) with 30 glaciers covering a total area of about 15 sq km. The total area itself points to the fact that these glaciers are not very large; none of them exceeds two kilometres in length. But what is interesting is the very fact that recent glaciers exist here, 1,000 km from the Sea of Okhotsk and just as far and further from the



The taiga near the Amur River

mountain glacier regions of northeastern Siberia and at a relatively low absolute altitude (the height of the snow line ranges between 2,100 and 2,400 m). Evidently, monsoon precipitation penetrates this far from the Far East.

Important and varied studies have been made in Soviet times of Lake Baikal itself. Soundings have shown that it is deeper than previously thought.

In the 1870s a point 1,373 m* deep was found in the lake near the source of the Angara. Later, an even deeper point, 1,522 m, was discovered and recorded as the maximum depth. Soviet maps show a new depth mark, 1,620 m, which makes the Baikal the world's deepest lake.** The 1,620 m depth was found opposite Olkhon Island.

Comprehensive studies of the lake were made by the Baikal Limnological Station of the Academy of Sciences of the USSR, which was long headed by Professor G. Y. Vereshchagin, an eminent Soviet student of lakes and Baikal explorer. The natural features of Lake Baikal make it unique. Soviet scientists have made extensive investigations into the origins of the lake's basin and its endemic fauna; they have studied its hydrological features, its distinctive animal life, the relief of its shores and islands and the present geological structure of the Transbaikal area.

Lake Baikal is of great economic value. It is an inexhaustible water supply source; a natural reservoir regulating the flow of the Angara; an important transport route; and a major source of fish. Enormous tracts of forest are concentrated in the Baikal basin.

The Transbaikal area is rich in mineral resources and its mineral springs rank with the waters of the best Caucasian resorts in their therapeutic properties. For this reason, the conservation and rational use of Lake Baikal and its natural resources are of great importance to the country and have been given careful attention in recent years by the scientific community.

Exploratory work has been carried on in the south of the Yakut ASSR and adjacent areas where the vast Aldan Upland rises up in the midst of remote expanses of taiga.

Studies of this region have in some instances given a more accurate picture even of the purely surface features of the relief, such as mountain peaks and the character of relief breakdown.

Substantial changes had to be made in the map of the central regions of the Yakut ASSR, in particular, the vast

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* Current maps show a depth mark of 1,415 m in this part of the lake.

** Lake Tanganyika in tropical Africa (the world's second deepest lake), which is similar to Lake Baikal in many ways, has a maximum depth of 1,435 m.

Lena-Vilyui Lowland. The River Linde, for example, found its way onto the map for the first time, and the course of the Markha, Tyung and others had to be redrawn.

Extensive studies of Central Yakutia were made in the 1920s and early 1930s by the Yakut Commission and the Yakut Expedition of the Academy of Sciences of the USSR. Many eminent scientists took part in this work: geographer A. A. Grigoryev, geologist S. S. Kuznetsov, soil scientist A. A. Krasyuk, geobotanist and soil scientist R. I. Abolin, and others. As a result, a number of interesting works were written, including summary works on the geology and geomorphology of the Yakut ASSR that were published on the occasion of its tenth anniversary. They illuminated many till then unclear features of the central part of Yakutia. Later, diamond and natural gas deposits were discovered in the Vilyui River basin.

Numerous expeditions to the Central Siberian Plateau introduced many changes in the map of that region, especially of its western part. Work done by S. V. Obruchev between 1917 and 1924 in the southern and western parts of the Tunguska coal-bearing basin revealed how incomplete the pre-revolutionary geographical data on the Central Siberian Plateau were. Part of the discovery of the above-mentioned basin must be attributed to S. V. Obruchev because he was the first to distinguish it as a separate economic and geological unit.

In the course of his geological explorations, S. V. Obruchev always took a lively interest in geographical facts and gave them a prominent place in his reports. His report on the expedition to the Central Siberian Plateau was outstanding in this respect. In the four years of the expedition's work a total of over 4,500 km was traversed.

S. V. Obruchev did not have at his disposal maps suitable for the geological studies he wanted to make. The only survey materials available from pre-revolutionary times related basically only to large rivers (the Angara and the Yenisei, for example), and not all of them at that. There was nothing among those materials on the Podkamennaya Tunguska River. However, a large segment of the river was mapped in 1921 by N. N. Kartashev, the topographer with A. Tugarinov's expedition. He also surveyed the route along the Chuna River. S. V. Obruchev made use of these surveys, but they covered only a small part of his route.

Obruchev also received an interesting map from V. P. Trofimenko, the head of the Poligus trading station on the Podkamennaya Tunguska. Trofimenko had drawn the map in 1923, from sketches made by local Tunguses. It depicted the vast territory between the Podkamennaya Tunguska and Nizhnyaya Tunguska rivers.

The absence of survey materials for a large portion of the ground it intended to cover forced the expedition to make route surveys. The upper parts of the Podkamennaya Tunguska, the Kureika and other tributaries of the Yenisei and the Angara were mapped on the basis of these surveys.

The expedition did some barometric levelling, that is, it determined elevations with the aid of aneroid barometers. Data on altitudes for the greater part of the Central Siberian Plateau were so skimpy that it was impossible to get even an approximate idea of the relief structure of the plateau's central area. The work carried out between 1917 and 1924 provided new altitude marks, making it possible to get a more accurate picture of the relief features of the plateau in the Podkamennaya Tunguska region.

While S. V. Obruchev was studying the Tunguska basin, exploration also began of the southwestern part of the Central Siberian Plateau. Instead of the latitudinal Pitsky Range, the map of this region acquired the outlines of the almost meridional Yenisei Ridge flanking the right bank of the Yenisei and reaching heights of over 1,000 m instead of the earlier known maximum of 857 m.

Subsequently, extensive exploration carried out in various parts of the Central Siberian Plateau gave a more precise and detailed picture of the relief structure and revealed other natural features. Large areas were photographed from the air in conjunction with the work done on the ground.

The author of this book took part in the exploration of the Yenisei River area north of Krasnoyarsk. Siberian taiga extends from the right bank of the river—dense forests of huge spruce, silver fir, pine and larch, with impassable undergrowth of young spruce and silver fir. And extending from the left bank of the Yenisei, directly opposite these wild, dense and trackless forest masses, were areas of cheerful forest-steppe. The contrast was amazing!

Important work was also done in the northern part of the Central Siberian Plateau by the Arctic Institute, which

carried out a series of geomorphological studies of the plateau. Interesting in this respect is L. G. Kamanin's book on its geomorphology.

Of considerable interest was the investigation of the River Olenek carried out by I. M. Suslov in 1934. In addition to a survey of the river, geological studies of the bank exposures and relief sketches using the contour line method were made, providing important geomorphological data.

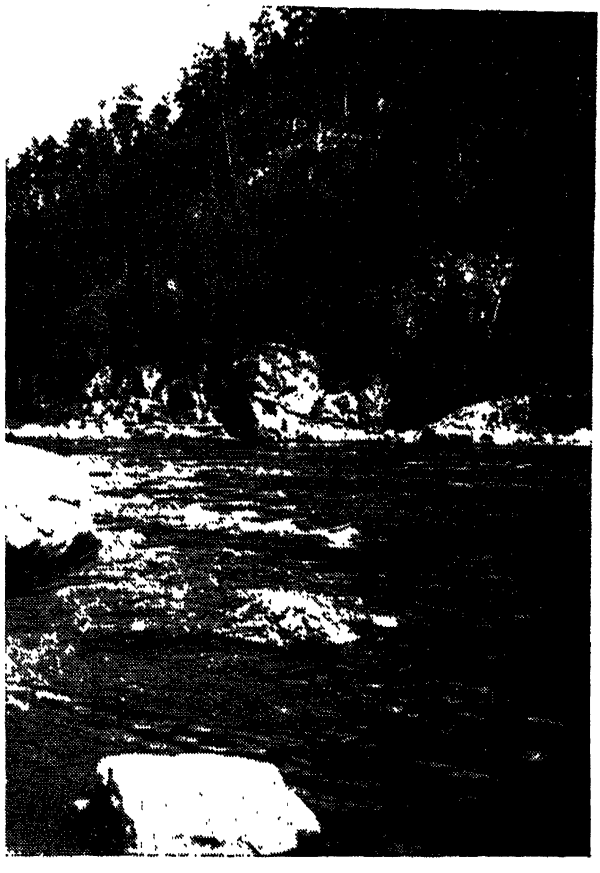
Suslov and his assistants pioneered the exploration of the Olenek. "The chances of finding a pilot were nil," wrote Suslov, "because none of the local nomads knew the navigational conditions of the Olenek throughout its length. Therefore, we went downstream following a course chosen mainly by our raft, and the latter was almost always carried along the channel, unless this picture was spoiled by the wind, which frequently blew our raft off the desired course because of the big tent on it that acted like a sail. In such cases, we stopped so as not to err in determining the channel" [61].

The explorers failed to reach the mouth of the Olenek. Near the end of the journey their raft had become water logged, covered with silt and overweight. Its draught increased, and the boards that served as a deck became submerged.

Below the mouth of the Uku River, the raft ran into a storm, giving its passengers an unexpected cold bath. After a four-hour battle with the strong wind in an effort to save their valuable materials, the travellers finally made it to shore on their half-wrecked raft. It was impossible to sail on it any further, and the boats on it turned out to be smashed as well. Thus, the survey of the Olenek had to stop at the mouth of the Uku.

In the northwestern part of the Central Siberian Plateau, a map of the Putoran Plateau and the region of the Norilsk lakes immediately west of it was drawn with the help of aerial photography. The Putoran Plateau turned out to be considerably higher than shown on earlier maps. It was determined that Mt. Kamen on this plateau rises to a height of 1,701 m. Physical geographers N. I. Mikhailov and Y. P. Parmuzin have given a comprehensive description of the Putoran Plateau.

Information on the natural conditions and resources of all of Central Siberia, accumulated as a result of Soviet investigations, has recently been summarised.



At the lower reaches of the Kan River

As concerns the West Siberian Plain, more than just the map of its northern part had to be changed considerably. Even in the south—in areas relatively near the railroad, large water transport arteries, the Ob, the Irtish, and some rather large towns—there were places that had long remained blank spots on the map and were accurately mapped only in Soviet times.

Extensive exploration of the West Siberian Plain was undertaken in recent times, after geologists discovered rich deposits of oil and gas there, opening up broad prospects for the economic development of this in large part completely unpopulated territory of taiga and swampland. Now, for

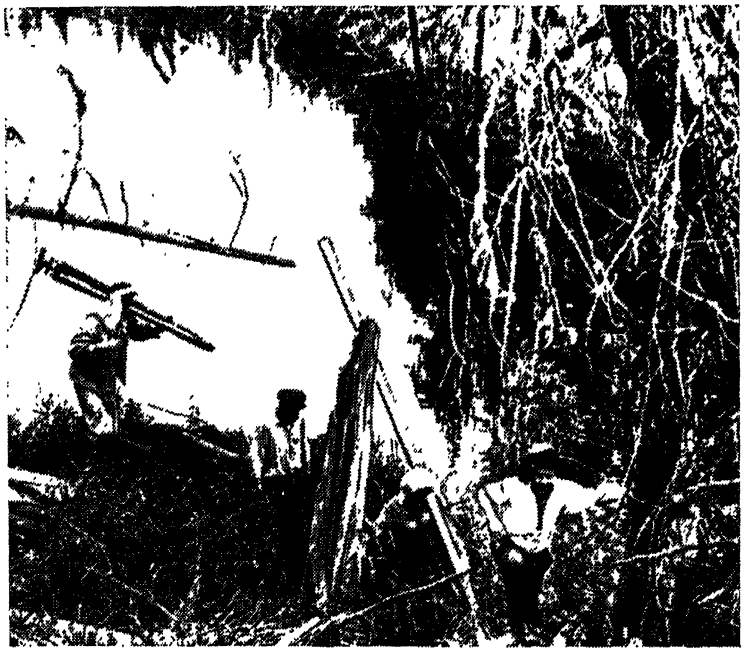
the first time, we have a complete and accurate picture of the geography of this region.

Soviet exploration of the mountain systems in southern Siberia introduced some substantial changes in our conception of its relief and enabled cartographers to draw more accurate maps. In the Sayany and Altai mountains new lakes and numerous glaciers have been discovered.

In 1927, N. V. and V. V. Lamakin explored Eastern Sayany in the watershed area between the Irkut River in the north and the Ura River in the south, an area that had never before been visited by scientific expeditions. They ascertained the arrangement and elevations of the mountain ridges and peaks, the direction of the valleys, and the geological and geomorphological features of the region, while simultaneously making observations of the vegetation and animal life.

It was no easy task for expeditions to carry out geodetic and topographical work in the Eastern Sayany at a time when there were no accurate maps and many of the remote and almost inaccessible regions were being explored for the first time. They had to make their way through trackless wilderness into the heart of the mountains, and drag logs up onto bald summits to build geodetic signals (pyramids) there. A book by engineer G. A. Fedoseyev [62] gives a detailed description of the work and life in the mountain taiga of a small geodetic expedition outfitted in 1938 in Eastern Sayany. Bears destroyed their shed containing food supplies and equipment, so the party, left without flour, salt and sugar, had to depend on what the taiga had to offer. But none of the hardships caused by lack of food supplies, clothing and footwear, or by the trackless wilderness and whims of the weather could stop the travellers.

Ultimately, the expedition penetrated into the central part of the Eastern Sayany. There, in the heart of the mountain system, they waited in the hope that food and other supplies might be dropped to them from an airplane. But no help came; there was nothing else to do than, exhausted and half-starved, not having seen a piece of bread for a long time, to make their way out of the embraces of the mountain taiga. Later, they learned that boats with men and supplies sent to them down the Kizir River had crashed into some cliffs. Two men had been killed, and another two were badly injured, but rescued by local fishermen and taken to hospital.



Geodesists in the taiga

The two survivors were able to inform the people in Novosibirsk of the party's needs. But by the time a plane was dispatched, the party had already made their way down from the mountains.

After the geodesists, topographers and geographers, into the mountains went geologists, botanists and more geographers, all with the aim of making a comprehensive study of the geography and natural resources of the Eastern Sayany. In the course of these studies, many discoveries were made.

On the basis of explorations carried out by S. V. Obruchev between 1939 and 1945, a new orographic diagram of the eastern half of the Eastern Sayany was drawn up. The structure and origins of the relief of this mountain region were revealed and a new glacier area discovered. Obruchev found a group of glaciers between the Tissa and the Sentsa (left tributaries of the Oka), along the upper Sentsa and in the upper reaches of the Khamsara (glaciers in the Tuvin part of the Eastern Sayany, in the area of Topographers' Peak,

were also investigated by M. G. Grosswald and G. M. Tomilov). S. V. Obruchev continued his explorations of the Eastern Sayany in 1946 and in 1953-1954.

Located in the upper reaches of the Zun-Bulag (Dzhon-Buluk, Dzhon-Balyk), a left tributary of the Oka, is one of the most interesting volcanic regions in Siberia. Lava emissions have taken place along cracks connected with the fracture zone of the southern slopes of the Oka Ridge. Two small but excellently preserved volcanic cones with craters rise up from the lava flow in the upper reaches of the Zun-Bulag.

These two volcanoes had been known since long ago. They were first visited in the 1850s by the English artist Atkinson, and P. A. Kropotkin described them in 1865.

In 1914, geologist S. P. Peretolchin, the man who explored Lake Khubsugul (Kosogol) and the glaciers of Munku-Sardyk, set out to investigate the volcanoes. He penetrated the upper Zun-Bulag, but died under mysterious circumstances without reaching his goal. The following year his skeleton was found on a lava stream, one and a half kilometres to the north of the northeastern volcano. It is surmised that he was killed by his companion.

S. V. Obruchev, who explored these volcanoes in 1940, suggested the names they now carry: Kropotkin Volcano (on the south-west) and the Peretolchin Volcano (on the north-east).

It was later found that besides the two volcanic cones described by P. A. Kropotkin, there is another one, albeit destroyed, located 500 m from the Kropotkin Volcano.

In the western half of the Eastern Sayany mountain range, geologist G. I. Stalnov discovered (in 1925) recent glaciers in the Kizir-Kazyr Range (the Kryzhin Range) and at the junction of the Kanskoye Belogoriye and the Agulskiye Belki (in the upper reaches of the Orzagai River in the Agul River's system of sources). In this same area and on Mt. Piramida in the Kanskoye Belogoriye two new glaciers (the Agulsky and Ilyin glaciers) were discovered in 1948-1949.

An expedition of the Institute of Botanics of the Academy of Sciences of the USSR (1948-1949) discovered a large error in the mountain elevations shown on former maps. According to the maps that the explorers started out with, Mt. Piramida was higher than Grandiozny Peak, when in fact it was

the other way around.* This was the first time that botanists had ever gone to those almost inaccessible parts of the Sayany mountains. The main result of the expedition, therefore, was the filling in of a large blank space in the vegetation map of the USSR.

Important geographical exploration and discoveries have been made in the Tuva ASSR, which lies in the very centre of Asia and is distinctive in its transitory features ranging from the bald mountains (*goltsi*) and mountain taiga of southern Siberia to the typically Central Asian landscape. Before Tuva became part of the USSR it had been little explored, some of its ranges did not have definite names**, and maps abounded in inaccuracies and errors. For example, the map would show a big lake where the first Soviet expedition actually found a high mountain. Geologists had either to make topographic surveys themselves or to invite specialists to accompany them. On the 1945 expedition, S. V. Obruchev made route surveys himself, which took up a great deal of time. On his next expedition, he invited Y. A. Meshcheryakov to handle those operations.

Obruchev's 1945 and 1946 expeditions were the first to cross northeastern Tuva in different directions. Besides discovering the glaciers in the Tuvinian part of the Eastern Sayany, as mentioned earlier, this expedition also discovered a vast basalt plateau with an ancient volcano in northeastern Tuva; a mountain mass between Bii Khem and Kaa Khem (that is, between Bolshoi Yenisei and Maly Yenisei) and the Bus-Bilinsky Depression. It explored the southern slopes of the Yergak-Targak-Taiga Range for the first time; put a number of rivers on the map that had never been shown before; made map corrections, shifting certain mountain ridges as much as 30 to 35 kilometres, thus "shortening" the rivers on one side of such ridges and "lengthening" those on the other; and provided the first picture of the geological structure and relief of the region [63].

Geological, geomorphological and physiographical investigations were subsequently made of the entire territory of the Tuva ASSR. Besides the volcano discovered by

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* A USSR hypsometric map with a scale of 1:2,500,000, published in 1949, showed Mt. Piramida at 3,292 m, while current maps set it at 2,256 m, and Grandiozny Peak at 2,922 m.

** One of the big ranges in eastern Tuva has been named after Academician V. A. Obruchev.

The Belukha mountain massif in the Altai

S. V. Obruchev's expedition on the basalt plateau in the centre of northeastern Tuva, another 15 volcanoes have been found there, all relating to the Quaternary Period.

The Western Sayany has also been extensively explored. One of the first Soviet explorers of that region was I. K. Bazhenov, who worked there in 1923. In his reports, he not only furnished geological data, but also information about the relief and the river network of the territory he studied along the Abakan, Yenisei, and Us rivers. Later on he published a summary work on the geology of the Western Sayany. Studies of that region were also made by S. P. Suslov, V. V. Reverdatto and others.

A great deal could be written about the exploration of the Altai in Soviet times, for extensive work has been done there. But perhaps the most interesting results from the standpoint of geographical discoveries came from the study of Altai glaciers.

M. V. Tronov, a Soviet scientist, a Siberian by birth and an eminent expert on Altai glaciers, wrote that "at the present time [1948—*N.G.*] we know of 754 glaciers in the Altai, with a total estimated area of 600 sq km. This is fifteen times more in number and four times more in area than was known to Sapozhnikov*; it is three times the number and twice the area indicated in the *Catalogue* of 1925. The descriptions, catalogue and maps of glaciers ... give a new, now more or less complete idea of Altai glaciation, one quite different not only from Professor Sapozhnikov's conception, but also from data in the latest reports published ten years ago" [64].

As early as the 1920s M. V. and B. V. Tronov made a series of trips through the Altai, in the course of which they discovered many new glaciers.

New glaciers were also discovered in 1928-1929 by L. I. Semikhatova in the mountains of southeastern Altai in the southern part of the Chikhachev Range. She named the glaciers after V. A. Obruchev, the Russian Geographic Society, the Geographic Research Institute and in honour of geographers Y. M. Shokalsky, S. G. Grigoryev, A. A. Borzov and others. Semikhatova also discovered some small glaciers in the Sailyugem Range.

After publishing his summary works on Altai glaciation, M. V. Tronov continued his study of the glaciers in that area. In 1949-1950, he headed an expedition of the Tomsk University geography department to southeastern Altai.

The expedition discovered 27 small glaciers primarily in the eastern part of the Yuzhno-Chuisky Range. The total number of glaciers in the Altai now exceeds 1,000. The area of the glaze is more than 900 sq km. In terms of its development, the Altai glaze today holds fourth place in the USSR, after the mountainous regions of Central Asia, the Caucasus and Koryak-Kamchatka.

Numerous Soviet expeditions have studied the geological structure, the geomorphology and physical geography of the

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* V. V. Sapozhnikov (1861-1924)—professor at Tomsk University, a prominent explorer of Siberia, especially of the Altai and Semirechye (the northeastern part of Central Asia), where he conducted botanico-geographic investigations and studied the relief and glaciers. He discovered a number of glaciers in the Altai and the Djungar Alatau mountains.

Sayany and Altai mountains, the Tuvinian Elevation and other mountains in southern Siberia.

The economic development of the eastern regions of the USSR and the transformation of Siberia from a backward agrarian and hunting territory into a territory with advanced industry and a powerful energy supply base have engendered a great demand for studying its natural features and resources. For further progress in the comprehensive exploration of Siberia and the Far East, a large geographical research centre has been established in Irkutsk: the Institute of the Geography of Siberia and the Far East, headed by V. B. Sochava. The institute comes under the Siberian Branch of the Academy of Sciences of the USSR. It organises both expeditions and stationary research. The basic task of the institute is to study the taiga and to develop a scientific basis for the rational use and development of its resources.

CHAPTER 8

GEOGRAPHICAL DISCOVERIES IN THE MOUNTAINS OF CENTRAL ASIA

Nature in Central Asia is full of contrasts. Here the highest mountain ranges in the USSR are in direct proximity to deserts and steppes.

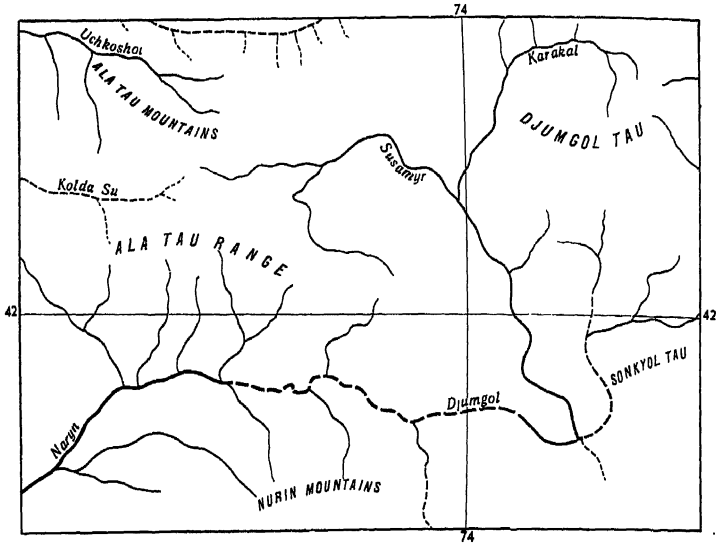
D. I. Shcherbakov

From the standpoint of physical geography the Tarbagatai Range may be considered the boundary between Siberia and Central Asia. To the south lies the Djungar Alatau, one of the basic Central Asian mountain systems.

In Soviet times, extensive geological, geomorphological and botanico-geographical explorations have been carried out in the Djungar Alatau mountains, including the summit regions with their fairly large glaciers.

Before the revolution, the Djungar Alatau glaciers were only partially known. In the early part of this century, they were studied by S. E. Dmitriyev and V. V. Sapozhnikov, but their explorations did not cover all of the glacier region there and were sometimes of very short duration.

Since the revolution, the glaciers of that region have been thoroughly studied by special glaciological teams. Now, the map of the huge region of modern glaciation in the Djungar Alatau mountains, at the upper reaches of the left sources of the Lepsa River and in neighbouring areas, shows glaciers named in honour of Soviet geographers Berg and Kalesnik. One of the valley glaciers was named in honour of Academician K. I. Satpayev, and another was named after the remarkable Kazakh scientist and traveller, Ch. Ch. Valikhanov. Mountain peaks have also been given such names as Berg's Peak, Satpayev's Peak, Valikhanov's Peak, etc. As a result of Soviet explorations, it has been



Map of the northwestern region of the Interior Tien Shan made prior to the USSR Academy of Sciences expedition of 1933

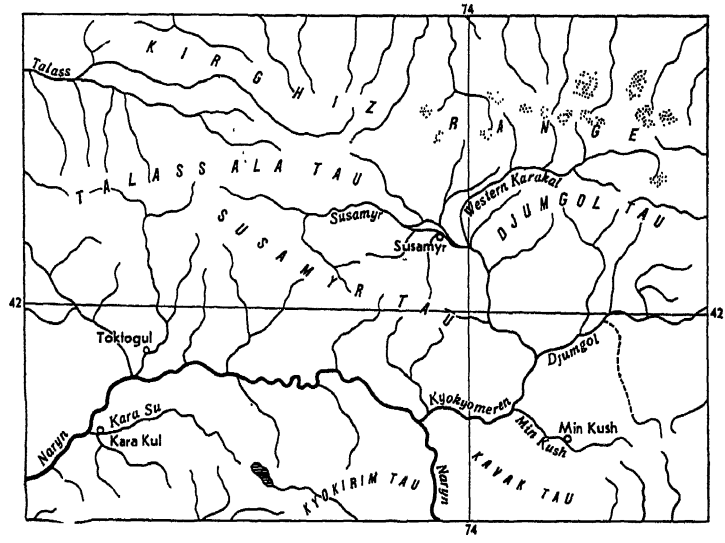
established that the area of glaciation in the Djungar Alatau mountains (within the USSR) is 956 sq km, that the number of glaciers there is 724.

* * *

The pre-revolutionary map of the Tien Shan mountain chain contained some fairly large blank spaces.

A number of previously unexplored parts of the Tien Shan were visited (between 1921 and 1932) by N. L. Korzhenevsky, a well-known explorer of the mountains of Central Asia. In a number of instances, his work resulted in major corrections in the map (for example, of the Kirghiz Range) and the discovery of new glaciers (in the upper reaches of the Susamyr).

North of the Ferghana Valley between the gorges of the rivers Uzunakhmat and Atoinak, or Karakuldzha (the Naryn basin), a high range, with snow-capped peaks rising to a height of 3,900 m (there is now a 4,164 m elevation mark here), was discovered in 1930. Geologists V. A. Nikolayev and V. N. Ognev, who explored the range, suggested calling it the Uzunakhmat Tau Range, and renamed the range



Present map of the northwestern region of the Interior Tien Shan

carrying this name on earlier maps the Atoinak Range, after a river of the same name.

Old maps had a huge blank space at the confluence of the Naryn and Kyokyomeren rivers in Interior Tien Shan. In the early 1930s an expedition of the Academy of Sciences of the USSR worked in this area for two years. This is what geographer E. M. Murzayev, a member of that expedition, wrote: "Lying hidden in the middle of Kirghizia and surrounded by high ridges is a remote and little known mountain mass, in the heart of which is located the picturesque Kavak Tau. Until recently, this area was not filled in on any maps. Rivers were shown by dotted lines and flowed in undetermined directions, without any indication of where they began or ended. The ways here are narrow, and puzzling paths lead the traveller further and further into the distant unknown territory. One is constantly struck by the untouched wilderness and the grandeur of the mountain landscape" [65].

Overcoming great hardships, the expedition made its way by pack horse over narrow rocky paths, and sometimes with no paths at all, along steep slopes high above turbulent mountain streams, now climbing up to high passes and then descending into valleys, sometimes having to ford treacherous rivers and get around inaccessible cliffs. In this way,

Landscape high in the plateau region of the Interior Tien Shan

the expedition criss-crossed a large blank space. It proceeded slowly, at times covering only six or seven kilometres a day. Along the way, the party made route eye surveys and determined the elevation at selected points with the help of a barometric altimeter. A special team made geological examinations.

Upon completion of the field work done in 1933, E. M. Murzayev drew up a new map by making use of his own expedition's route surveys and tying together a number of unconnected topographical surveys of different sectors of the blank space made earlier by other explorers. His map was substantially different from any previous map. The course of the Dzumgol and Susamyr rivers was changed, and their point of confluence moved back a good distance. The Kirghiz Range had to be "shifted" to the south (by 25-28 km), and as a consequence the Susamyr's tributaries became much shorter, while the rivers on the northern slope of the ridge were lengthened. The map now showed many more of the tributaries of the Kyokyomeren and other major rivers.

The Kavak Tau mountains with the Minkush River separating them appeared on the map for the first time. They consist of two ranges, extending for 120 km, with passes

lying at an elevation of about 3,000 and individual peaks reaching 3,700 m, that is, the perennial snow line.

Thus, a big blank space in the Interior Tien Shan was filled in. Not so many years have passed since then, but what tremendous changes have taken place there! New settlements have sprung up; Naryn coal is now shipped by rail to the cities and towns of Central Asia; large mines with the latest technology have replaced the primitive lead, copper and coal pits.

Extensive work is being conducted to supply electricity to the Interior Tien Shan. A large hydroelectric power station, the Uchkurgan station, has already been built on the Naryn, and another, the Toktogul station, is under construction. A veritable cascade of power stations is planned for this river, and several stations for its tributaries. Collective farm power stations have long been in operation. The major transport routes of Kirghizia now pass through the territory of the blank space filled in by the Academy of Sciences expedition: the Frunze—Susamyr—Osh highway, and the road branching from it in the Susamyr hollow and going through Chayek and Cholpon to the Rybachye—Naryn—Torugart Pass highway.

* * *

For a number of years (between 1929 and 1933, inclusive), Ukrainian expeditions, headed by M. T. Pogrebetsky, I. A. Adamovich and I. I. Lando, worked in the very heart of the Tien Shan in the vicinity of Khan Tengri Peak, where they made extensive topographical surveys and studied the geography and geology of the region.

In September 1931, members of M. T. Pogrebetsky's expedition climbed to the top of Khan Tengri, dispelling the myth about its inaccessibility. The achievement of the Soviet mountain climbers created a sensation abroad, for many experienced foreign mountain climbers had firmly believed that Khan Tengri could not be conquered. In 1930, a party of Moscow alpinists became the first to reach the glacier, Severny Inylchek, and gather information about that hitherto unknown region.

In 1932, a group of alpinists, led by A. A. Letavet, from the Moscow House of Scientists began the exploration of Central Tien Shan, and in subsequent years (1934-1938)

it developed into a full-fledged expedition. It made a number of geographical discoveries in the vicinity of Khan Tengri and in the Kokshaaltau and Kuilyu Tau ranges. The mountain climbers ascended Nansen] Peak (approximately 5,700 m) in the Inylchektau Range, and also the slope of a high, hitherto unknown peak rising to the south of Khan Tengri. At the foot of this peak, the party examined the Zvezdochka Glacier, which merges with the giant Inylchek Glacier.

* * *

A remarkable geographical discovery was made in Central Tien Shan in 1943. This was the discovery of Pobeda Peak, the highest point in the Tien Shan mountains and the second highest peak in the USSR.

It had previously been believed that the Tien Shan had no summit over 7,000 m and that the highest point was the top of Khan Tengri (6,995 m). But in 1943, an expedition of geodesists and topographers discovered a peak 7,439 m high. It was named Pobeda (Victory) Peak in honour of the Soviet Army victories in the Great Patriotic War. Pobeda Peak is south of Khan Tengri and is part of the Kokshaaltau Range. It stands in the highest and most glaciated region of the Central Tien Shan in the easternmost part of the Kirghiz SSR, near the Chinese border.

Many expeditions had penetrated this region, but because of its near inaccessibility none had succeeded in mapping it with sufficient accuracy or completeness. Prior to the 1943 expedition it remained in large part a blank space.

The discovery of Pobeda Peak came as a surprise to geographers. To be sure, the conquerors of Khan Tengri in 1936 saw the summit and even photographed it, but, having no scale for comparison, did not consider it to be outstanding in height.

In 1938, the press carried A. A. Letavet's report about a peak south of Khan Tengri "which can easily compete with Khan Tengri in height". However, its height remained unknown, so that no one knew that it was almost 450 m higher than Khan Tengri.

Members of the 1940 alpine expedition once got a glimpse of the summits of the Kokshaaltau from the Sarydjaz, when the former were not covered by clouds as they usually are. It appeared that they were higher than Khan Tengri, but

An expedition crossing the Sarydjaz River

there was no way of making sure. Moreover, reports of their impressions were not published at the time; this information came out only in connection with the 1943 discovery. It is no wonder, therefore, that it came as a surprise to everyone.

Taking part in the expedition, outfitted in May 1943 for the purpose of surveying 8,000 sq km of virtually inaccessible territory, were a phototheodolitic team, geodesists who were experts in triangulation, and an aerial photography team.

The mountain ridges and passes were still covered with snow, making it difficult to get food and forage to the target region. It was already June 29 when the first topographers headed into the mountains. The men had to work hard to beat a path through the snow in order to lead the pack horses over the passes. Sometimes, they had to carry the loads on their own backs. The altitude and rarified atmosphere made it that much harder. Throughout June and July and for 20 days in August it rained, with intermittent snowfalls, and the mountain summits were hidden in the

clouds most of the time. There was relatively good weather only between the end of August and October 5, but even on the best days visibility was satisfactory only during the first half of the day. Because of the heavy precipitation, the rivers were overflowing, and crossing them was extremely difficult. In mid-September, the swollen Lake Mertsbakher burst between North Inylchek and South Inylchek glaciers, sending water and ice with a thunderous roar at first over the glacier, and then into the Inylchek River. The topographers and geodesists were cut off from the expedition base for two weeks, but, fortunately, provisions reached them in time and everything ended well. However, climbing to the summits over glaciers and snow-covered rocky crests continued to involve great risks.

An interesting phenomenon was observed during a thunderstorm on the mountain tops. "In the moments just preceding a snowfall, hail or a thunderstorm and throughout the thunderstorms themselves, the air at the summits became so electrified that human beings and instruments became veritable theremins.

"Every movement, whether it is someone lifting a hand or a foot, or the fluttering of the cloth cassette of the phototheodolite, produces peculiar musical sounds. Your hair stands up on your head, and if you touch the metallic parts of instruments you get a strong electric shock and sometimes even small burns. Even if you grasp the wooden handle of an ice-axe while wearing gloves, you still get an unpleasant sensation. Since thunderstorms occurred almost daily and began around noon or one o'clock in the afternoon, we observed this phenomenon quite frequently" [66].

Being at a high altitude all the time the members of the expedition experienced painful skin sensations, especially at night.

Conditions for aerial photography were difficult. Flying weather with good visibility occurred very infrequently. Because of the extremely high altitudes at which the flights had to be made, the men in the planes had to wear oxygen masks. Any damage to the airplane could have caused a catastrophe since there were no convenient landing strips nearby.

In the course of their exploration, the members of the expedition spotted a peak situated south of Khan Tengri in the Kokshaaltau Range. It appeared higher than Khan

Pobeda Peak

Tengri, but they did not determine its exact location or height, figuring that they could do that after their field work was completed, when they processed their materials in the laboratory in Tashkent.

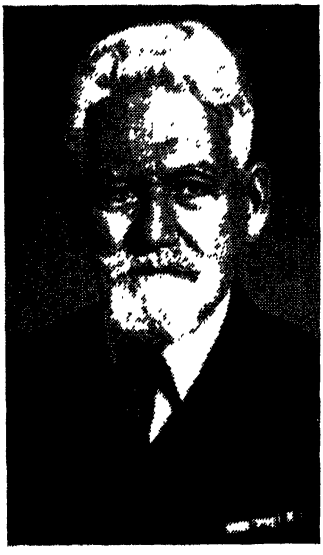
It took four months to process the materials, which included 379 phototheodolite stations* and 560 aerial photographs.

"In the course of processing the negatives of the phototheodolite pictures on a stereoautograph**, previously unknown peaks, with absolute height marks of 7,439.3 m and 6,873.0 m were discovered..." [67]. The 7,439 metre summit was named Pobeda Peak.

The outstanding geographical significance of the discovery of Pobeda Peak, the highest point in the Tien Shan mountains, was underscored by the awarding of the All-Union Geogra-

* A phototheodolite station is the point at which a phototheodolite stands as an area is being photographed and angular measurements taken in the course of a terrestrial stereophotogrammetric survey. A phototheodolite is an instrument consisting of a camera mounted on a theodolite.

** A stereoautograph is an instrument used in processing photographs taken with a phototheodolite for purposes of drawing up topographical maps.



L. S. Berg

phical Society's P. P. Semenov Gold Medal to the main participants of the topographical work, P. N. Rapasov, V. I. Ratsek, A. F. Koksharov, N. Y. Gamaleyev and A. M. Arutyunyants. The official statement, presented to the Academic Council of the Geographical Society of the USSR, said the following in this regard: "The discovery of Pobeda Peak and the drafting of the map of the area adjacent to it constitute not only a major contribution to geography, but a real geographical feat. It must be borne in mind that to make their surveys, the members of the expedition had, in the Terskei, Sarydjaz, Terekty and Maibash ranges, to climb peaks almost as high as Mont Blanc, to say nothing of the difficulties and hardships they faced as they trekked over mountains and gorges and across turbulent rivers and high mountain passes.

"The skilful scientific organisation of the entire undertaking and the personal courage and devotion to their work displayed by the members of the expedition have yielded fruit fully deserving being marked with the Geographical Society's high award, the Gold Medal bearing the name of P. P. Semenov, the first explorer of the Tien Shan"[68].

The surveys made by the topographers (under P. N. Rapasov) who discovered Pobeda Peak also revealed the exact contours and dimensions of Inylchek, the largest of the Tien Shan's glaciers. Various estimates of its size had been made before, but now it was possible to state with certainty that this huge valley glacier was almost 60 km long.

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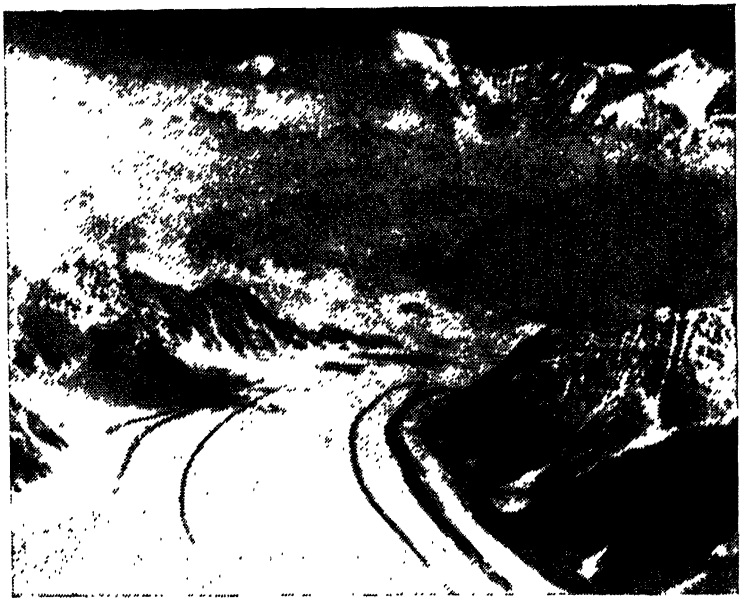
Between the Tien Shan's mighty Kungei-Alatau and Terskei-Alatau ranges lies the extremely picturesque Lake Issyk-Kul.



The central part of the Fedchenko Glacier. Communism Peak is seen in the background

In 1928, a USSR Academy of Sciences expedition under L. S. Berg made hydrological, hydrobiological and fish studies of the lake, in the course of which supplemental data on its depths were obtained, including a sounding of 702 m, now shown on all geographical maps as its maximum depth (the maximum depth of the lake was recently more exactly established as 668 m). Issyk-Kul is the third deepest lake in the USSR, after Lake Baikal and the Caspian Sea.

The comprehensive studies of the lake were not only of scientific value but also of great practical interest, particularly for the development of fishing. Studies of the Issyk-Kul basin are also important from the standpoint of determining the structure and the history of the formation of the Tien Shan mountains.

Soviet researchers have scored great successes in the geological study of the Tien Shan. Special mention should be made of S.S. Schultz's summary work, in which he brought together a great deal of geological and geomorphological material, giving a more accurate picture of the origins of

the Tien Shan's ridges and hollows than had existed before [69].

Special geomorphological and glaciological explorations were carried out in different parts of the Tien Shan mountains. Outstanding among the glaciological studies were those conducted by S. V. Kalesnik in Interior and Central Tien Shan. Detailed glaciological studies were conducted under G. A. Avsyuk at a Tien Shan high altitude station of the Institute of Geography of the USSR Academy of Sciences. The station, located on the northern slopes of the Terskei-Alatau and now being operated by the Academy of Sciences of the Kirghiz SSR, carried out extensive glaciological research in conjunction with the IGY programme. Expeditions organised by the station and by Moscow University's Department of Physical Geography have studied the high mountain watersheds (*syrt*) of Interior and Central Tien Shan.

Mountain climbers and local inhabitants of the Central Asian republics have contributed much to the relief and glacier studies of the northern chains of the Tien Shan.

The overall picture of glaciation in the Tien Shan system is now clear; the total area occupied by modern glaciers there is 6,566 sq km.

* * *

Major geographical discoveries have been made in Soviet times in the Pamirs. In 1928, the highest peak in the entire USSR was discovered in the Western Pamirs. This peak, 7,495 m high, was originally identified as Garmo Peak, which was known earlier. But finally, Soviet Pamir expeditions untangled the confusing arrangement of ranges and peaks in the Garmo knot and ascertained that this was an entirely different peak. It now carries the name Communism Peak. In 1933, Soviet alpinist E. M. Abalakov climbed the peak and N. P. Gorbunov, the head of a Tajik Pamir expedition, made it almost to the top. Four years later, a six-man mountain-climbing team mastered the peak.

Communism Peak is shaped like an obliquely truncated pyramid rising above the Fedchenko Glacier. Before the revolution, only the lower part of this glacier—discovered by V. F. Oshanin, a Russian explorer of Central Asia—was known. The middle and upper parts of what turned out to be

a 75 metre-long glacier were discovered by the 1928 Pamir expedition, at the same time as it discovered Communism Peak and the central part of the Academy of Sciences Range in which it rises. Besides Communism Peak, many other peaks, some close to and others even higher than 7,000 m, and a large number of glaciers were discovered in the Academy of Sciences Range.

Since the geographical discoveries in the northwestern Pamirs were very important, it is worth going into some of the details of their history.

N. L. Korzhenevsky

The 1928 Pamir expedition had a predecessor in the work of filling in the great Pamir blank space. This was N. L. Korzhenevsky, who before the revolution made frequent trips to the Muksu gorge and the Fedchenko Glacier. He discovered the Mushketov and Fortambek glaciers and an extremely high peak (7,105 m), which he named Korzhenevskaya Peak, and made surveys of the Mushketov Glacier and the terminus of the Fedchenko Glacier.

Korzhenevsky continued his work after the revolution, exploring the Muksu River basin and its glaciers even more extensively. In June 1924, he climbed onto the Fedchenko Glacier; was the first to visit the Tanymas Glacier valley, situated at the terminus of the Fedchenko Glacier; explored the Muksu valley to the end of the Mushketov Glacier; and determined the height of Mt. Muzjilga (6,475 m)*, which rises in the northern extremity of the Academy of Sciences Range.

He also conducted important explorations of this region in 1926. The results of this work, along with his previous

* The exact height is now recorded as 6,298 m.

observations and data gathered by other explorers, served as the basis for his well-known work, *Muk-Su and Its Glaciers* [70]. Korzhenevsky then carried out additional explorations of the valley and glaciers. "In ascending Fedchenko Glacier," he wrote, "it was possible, because of the absence of clouds, to ascertain the sources of the Tanymas Glacier and establish the existence of a mountain range extending from Mt. Muzjilga to the south-southwest and crowned in this area with a huge ice-capped summit."

The explorer determined that the range, or "meridional elevation", extending from Muzjilga Peak forms the watershed of the Muksu, Garmo and Vanch rivers and is one of the "remarkable and unusually high elevations in all of Central Asia".

That meridional range had no name at the time. Korzhenevsky noted its extremely important role "in the structure of the glacier region on the Pamir-Darvaz border", and he proposed "to name this chain the Academy of Sciences Range in honour of the Union Academy of Sciences, which holds such an eminent and honoured place in the work of exploring Central Asia" [71]. In *Muk-Su and Its Glaciers*, the explorer described the geological structure of the range, its summits and the relief of its northern part. He also gave information about the range's glacier forms and about the glaciers at the crest, pointing out the role that its snows and névé fields play in feeding the Fedchenko Glacier and its left tributary, the Bivachny Glacier. Korzhenevsky also pointed out, and this was confirmed by later explorers, the favourable arrangement of the Academy of Sciences Range in relation to the moisture-bearing southwestern air currents. It accounts for the high level of precipitation at the upper end of the Fedchenko Glacier and the consequent lower snow line there.

In 1925, in between his exploration of the upper Muksu, the lower part of Fedchenko Glacier and the northern extremity of the Academy of Sciences Range, Korzhenevsky, with great difficulty, made his way into one of the most remote regions of the Pamirs, at the upper reaches of the Tanymas River*, where he reached the Muzkulak Glacier (now called the Grumm-Grzhimailo Glacier).

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* The near inaccessibility of this region is reflected in the very name "Tanymas", which in Tajik means "thou shalt not know me".

Thus Korzhenevsky succeeded in partially deciphering the northwestern edge of the blank space (the northern extremity of the Academy of Sciences Range between the Mushketov Glacier and the lower part of the Fedchenko Glacier) and its eastern outskirts (the upper reaches of the Tanymas River). However, prior to the 1928 expedition a vast area in the northwestern Pamirs remained unexplored. And that is the very region where the basic parts of the Fedchenko Glacier system and of the Academy of Sciences Range lie.

The Pamir high altitude expedition of 1928 was composed of several sections. These included sections of general geography, topography and geodesy; meteorology and geophysics; geology and mineralogy; zoology, biology and botany; ethnology and linguistics; radio communication; scientific and sports cinematography, and a section of high altitude ascents. The expedition was, therefore, comprehensive in nature, but its main task was to draw up a map and give a general geographical description of the unexplored regions of the northwestern Pamirs [72].

The expedition's personnel included Professor of the Central Asian State University N. L. Korzhenevsky; astronomer of the Pulkov Observatory Y. I. Belyayev; engineer and geodesist K. V. Isakov; topographer I. G. Dorofeyev; geologist of the Academy of Sciences, Professor D. I. Shcherbakov (later an academician); and O. Y. Schmidt and N. V. Krylenko, who headed and took part in the mountain climbing ascents. In addition, a number of German scientists and mountain climbers took part in the expedition. Of the work done by the German specialists, the most important was in the line of photogrammetric surveying. However, the credit for most of the discoveries made belongs to the Soviet explorers. The entire expedition was headed by N. P. Gorbunov.

Korzhenevsky, whose work related to the section on general geography, concentrated on the exploration of the Alai Valley and the northern outskirts of the Pamirs. He discovered and described a new glacier in the Trans-Alai Range, which the expedition named the Korzhenevsky Glacier.

D. I. Shcherbakov, who as deputy head of the expedition had his hands full with the work of organising the expedition, also carried out a mineralogical exploration of the northern

I. G. Dorofeyev

slopes of the Alai Range and of the Tanymas, Kudara and Bartang river valleys.

Astronomer Y. I. Belyayev and geodetic engineer K. V. Isakov handled the job of establishing control points for topographical studies and phototheodolitic surveys. Measurement of altitudes (with the help of hypsothermometers) was also included in the work programme of the meteorology and geophysics section.

Topographer I. G. Dorofeyev made an exceptionally large contribution to the overall effort. He surveyed several thousands of square kilometres of theretofore unexplored terrain. Working in extremely difficult places and at high altitudes, often as a member of mountain climbing teams, he covered more than 700 kilometres making plane-table and semi-instrumental surveys of the area.

Dorofeyev's surveys consti tuted a substantial supplement to the expedition's photogrammetric work, making the overall area surveyed significantly larger. His efforts were especially valuable in that he had traversed "dead spaces" not covered by the photogrammetrists.

He was the first to survey the upper reaches of the Vanch and Yazgulem and the upper Tanymas with its glaciers, and to determine the possibility of going from the Tanymas along the Fedchenko Glacier into the valley of the Muksu.

Dorofeyev discovered more than 20 new glaciers in the Fedchenko Glacier system. He was the one to establish the fact that the Fedchenko Glacier passes by the upper Tanymas and that it is 70 km long. The honour of discovering the middle and upper parts of this glacier belongs to him and Y. I. Belyayev. Dorofeyev also saw the peak rising above the Fedchenko Glacier—now called Communism Peak.

When Dorofeyev ascended to the pass from the upper Tanymas (Tanymas Pass), a spectacular panorama of the

giant glacier opened up before him.* He wrote: "We saw a glacier three to four kilometres wide and about 30 kilometres long. Its upper end, with its numerous side tributaries, came up against the snow-white wall of a range of some kind. The slopes flanking the mountain valley were covered with perennial snow, and only here and there could a black cliff be seen.

"Near the pass, the glacier turned sharply to the north-west.... Against the overall white background, black strips of medial moraine were visible" [73].

About fifteen kilometres from the pass the continuation of the glacier disappeared from view behind a bend in the slope. Directly opposite the pass, however, a wide and very beautiful glacier joined the main one from the south-west. Dorofeyev named it the Academy of Sciences Glacier.

"Looking down along the glacier," the explorer wrote, "we saw a high rocky range (the Academy of Sciences Range—*N.G.*) in which one bifurcated peak was particularly prominent. It was higher than the others but rising even higher was the irregular, truncated pyramid of a giant peak that clearly predominated over the entire range. It never entered my mind at the time that before me was the highest point in our country" [74].

Dorofeyev returned to the upper reaches of the Tanymas to spend the night by a lake, and on the next morning he went up to the pass again.

With renewed energy, he and his assistants went forward to penetrate the secrets of the mysterious glacier. But first they had to decide which way to go from the pass, down or up the glacier. They decided on the former in order to determine the extent of the glacier more quickly. And so, they made their way down the gentle slope of the unknown giant glacier. Dorofeyev later wrote: "It was a pleasant sensation to be walking in places where no man had ever set foot before.... One by one, new glaciers, peaks, ranges and passes appeared on the map I was drawing."

The temperature was as high as 24°C in the daytime. The snow became powdery and their feet sank in it. Beautiful

* The mountain climbers from the same expedition and astronomer Y. I. Belyayev had come upon the Fedchenko Glacier from the upper reaches of the Tanymas River before Dorofeyev, but they did not go down the glacier and did not establish the fact that that was the Fedchenko Glacier discovered by V. F. Oshanin.

turquosite streams with clear, transparent water ran down over the surface of the huge glacier.

At the bend of the glacier the explorers saw the first crevasses. At first they were small, covered over with snow. But further on they grew in number and in size, some up to ten metres across. The topographers made their way with difficulty across such fissures over thin and narrow snow bridges. Finally, Dorofeyev was certain that they were on the Fedchenko Glacier, the lower part of which was already known.

Wrote Dorofeyev: "It is hard to overestimate the significance of this discovery: not only was the presumed arrangement of the ranges in the 'blank space' region changed, but the Fedchenko Glacier itself turned out to be one of the largest mountain valley glaciers in the world, with a length, according to our measurements, of about 76 kilometres*. And so, we found ourselves on the Fedchenko Glacier!" [75]. Thus, the full picture of that glacier emerged for the first time. Measurement of its area and length established the fact that it is the largest mountain valley glacier in the USSR and among the largest in the world.

After the areas of other glaciers surveyed by Dorofeyev were computed, it was found that the total area of glaciation in the Fedchenko Glacier system exceeded 900 sq km.

The data gathered by Dorofeyev and other members of the expedition provided the basis for all subsequent maps of the Fedchenko Glacier system and of the Western Pamirs.

While the expedition focussed primarily on the northwestern Pamirs, it also explored the northern Pamirs (the Trans-Alai Range) and the Alai mountains, the Lake Kara Kul region, and parts of the southwestern Pamirs.

The year 1928 marked a turning point in the exploration of the Pamirs and the entire Pamir-Alai mountain system.** From that time on, the study of the region was not conducted by individual explorers, as before, but by large, excellently equipped and organised expeditions.

The work of the Pamir high altitude expedition of 1928 was continued by the Tajik Comprehensive Expedition of the USSR Academy of Sciences, to be referred to later as

* According to the latest measurements, the Fedchenko Glacier is 77 km long, which means that the 1928 determination was accurate.

** The term, Pamir-Alai mountain system refers to the entire mountain region of Central Asia south of the Ferghana Valley.

the Tajik-Pamir expedition. The expedition's mountain climbing team explored the Academy of Sciences Range from the Fedchenko Glacier side, while geologists and topographers studied the western side. In 1931, when the expedition was investigating the upper reaches of the Obikhingou River, it was learned that the peak which local inhabitants of the Darvazian village of Pashimgar called Garmo was not the 7,495 m one that the 1928 expedition had assumed was Garmo Peak, but one located much further south (also in the Academy of Sciences Range). It became clear that the 7,495 m elevation applied to an unnamed peak and not to Garmo Peak. That new, formerly unknown peak turned out to be the highest in the USSR.

These explorations of the Academy of Sciences Range filled in the last part of the blank space in the northwestern Pamirs. The overall length of the range turned out to be about 108 km. Twenty-four of its peaks were found to exceed 6,000 m in elevation, and two were over the 7,000 m mark. The crest, according to Korzhenevsky's calculations, has an average elevation of 5,757 m.*

"If the Academy of Sciences Range is compared with the Bernese Alps which have an average elevation of 3,469 m ... it turns out that the Academy of Sciences Range is 2,288 m higher than the Bernese Alps with their famous peaks, the Mench, Jungfrau, Finsteraarhorn, etc." [76].

Geologists of the Tajik-Pamir expedition gave an entirely new conception of the tectonic structure of the Pamirs and of the relationship between the Pamirs and the Tien Shan. They drew a general picture of the geological structure and history of the Pamirs (D. V. Nalivkin and A. P. Markovsky) and studied the mineral riches of the Pamir-Alai mountain system (A. E. Fersman and D. I. Shcherbakov).

The expedition's geographers made a detailed investigation of the Lake Kara Kul (N. L. Korzhenevsky) and studied the geographical features of the mountain regions of Tajikistan (I. S. Shchukin and others).

A big role in the exploration of the Pamirs was played by an expedition of the Second International Polar Year (2nd IPY), which worked in 1932 and 1933, primarily in the northern and especially in northwestern parts of the Pamirs,

* Korzhenevsky determined that the average crest elevation of the Academy of Sciences Range is less than that of Trans-Alai Range.

An expedition in the Trans-Alai Range

in close contact with the Tajik-Pamir expedition and even as a component of it. A special Fedchenko Glacier expedition called the Pamirs Glaciological Detachment was organised as part of the 1932 Tajik Expedition of the USSR Academy of Sciences. In 1933, this was the 21st Detachment of the Tajik-Pamir expedition and was headed by V. I. Popov.

To determine what changes had taken place since 1928 on the Pamir glaciers, Dorofeyev made a new photogrammetric survey of the Grumm-Grzhimailo (Muzkulak) Glacier and, jointly with other geodesists, took measurements to gauge the movement of the Fedchenko Glacier.

The Pamirs expedition of the 2nd IPY carried out extensive glaciological investigations in the northwestern Pamirs. The expedition's geomorphologist, K. K. Markov, working in the northern part of the Pamirs, studied the ancient glaciation of the Pamirs in its relationship with recent glaciation. Later he published an article summarising the current knowledge about the relief of the Pamirs.

During the 1932-1933 explorations, the world's highest hydrometeorological observatory was built on the Fedchenko Glacier (at an elevation of over 4,200 m). The men who built

the observatory and those who spent the first winter in it had to overcome extreme difficulties.

Exploration of the high altitude glacial regions of the northwestern Pamirs was continued in subsequent years.

In 1947 and 1948, Soviet alpinists and geographers worked in the Peter I Range, where it joins the Academy of Sciences Range and where the two together comprise the highest region of the Soviet Pamirs. They ascertained the exact arrangement of the ridges, peaks and glaciers in that area and studied its big glaciers (Sugran, 24 km long; Gando, 22.5 km long). They also drew up the first map of the Pamirs névé plateau (over 6,000 m elevation), situated between Moscow Peak in the Peter I Range and Communism Peak. New names appeared on the map: Moscow Peak, the highest point in the Peter I Range (6,994 m), Leningrad Peak (6,733 m), and Thirty Years of the Soviet State Peak (6,440 m). Many peaks in the Peter I Range were named in honour of Russian travellers and explorers of Central Asia and Soviet geographers (Oshanin, Lipsky, Shokalsky, Schmidt, Markov, Shchukin, Gerasimov, Grigoryev and others).

During explorations in the westernmost parts of the Peter I Range and on the southern slopes of the Alai Range in the Surkhob basin, the author of this book, together with K. M. Mirzayev and V. M. Muratov, had occasion to introduce some changes in the then existing map and to get more precise data on the contours and size of many glaciers.

One of the first things to attract attention was a nameless summit (4,205 m) rising picturesquely in the form of a sharp peak at the upper reaches of the Shurak River, which joins with the Nazarak River near Tajikabad. The peak rises up over the Kyzylkul Glacier on the right side of the river. It was named Shchukin Peak, in honour of Professor I. S. Shchukin, the eminent Soviet geographer and founder of the Moscow University's chair of geomorphology.

An expedition of the Moscow State University's Department of Geography worked under Professor Shchukin in the region of the Vanch Range in the Western Pamirs (1948-1950). An important part of that expedition's work consisted of studying the glaciers at the sources of the Vanch and Yazgulem rivers.

Extensive explorations in the northwestern Pamirs were carried out during the International Geophysical Year

(IGY). The Academy of Sciences of the Uzbek SSR was asked to organise the study of the Fedchenko Glacier. Overcoming great difficulties, the expedition's caravans slowly made their way from the upper reaches of the Tanymas to the upper part of the glaciers. There, right on the ice and névé, at an elevation of about 5,000 m, the expedition set up a drifting scientific station, which was named the Vitkovsky Glacier Station*. The last deliveries of supplies and equipment were made in October, when winter had already set in and the snows and snowstorms had begun. The horses froze on the glacier and, because of a dearth of fodder, became weak and perished. Temperatures reached—36°C. The men had to pack the last batch of equipment from the upper Tanymas on their backs. But then, airplanes came to their assistance, dropping containers of supplies and equipment onto the glacier by parachute. Life in the winter camp gradually began to adjust itself.

At the end of November, the wintering party made a trip for provisions to the closest base along the upper Tanymas, but found that it had been buried in an avalanche. Again, airplanes came to the rescue. And so it was that the party greeted the New Year of 1958 with a replenished food supply and even with a fir tree (albeit artificial, but decorated according to tradition) and champagne.

Cooking proved to be quite difficult. At an altitude of 5,000 m, meat stayed raw even in rapidly boiling water, rice and beans would remain undercooked, while starchy foods would spread out and form a paste, making it impossible to cook them properly. The ice under the little house kept melting, so that the men often had to straighten the floor. As it was, their time was fully taken up with exploring the area, working at the glaciological observation sites and making snow surveys.

During the winter, the station hut was covered with snow, and at the end of summer, it had to be dragged out of its icy pit onto the level surface of the glacier. Food deliveries were irregular, and the men had to go long distances over the ice and across its many dangerous cracks to meet caravans or to get to the neighbouring observatory station.

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* It was named after a large right tributary of the Fedchenko Glacier. It was opposite its mouth that the station was set up.

Two of the men who manned the station took part in a nine-man assault of Communism Peak in 1958, taking with them from the station instruments for ultra high altitude meteorological observations.

The station continued its operation the following winter with a partially rotated and augmented crew. Airplanes were again used to drop food, equipment and fuel. The book, *Drifting Station Above the Clouds* [77], gives a good description of how this moment was perceived from the ground, or more precisely, from the ice, by the wintering party. I, too, had an opportunity to watch one of those operations from the air.

It was October 7, 1958. At 11:30 a.m. our big four-motor airplane took off from Tashkent and we were soon flying over the Mogoltau mountains, the Syr Darya River, the foothills of the southern fringe of the Ferghana hollow, and the mountains of the Alai Range. Then we flew over the village of Daraut-Kurgan in the Alai Valley, across the Kyzylsu and soon below and ahead of us (we were flying at an altitude of 7,500 metres) lay the magnificent panorama of the northwestern Pamirs. Now and then our view was obscured by oncoming clouds, but when they parted we could see all the great mountain masses. There was Communism Peak, and then the sharp ridges and peaks at the upper end of the Fedchenko Glacier. Now the glacier itself, with its long, brown and amazingly distinct strips of moraine, was right below us. The upper reaches of the glacier were covered with snow, for winter was in full swing here. The fresh snow sparkled in the sunshine.

At 12 hours 50 minutes we were already directly above the upper end of the glacier. Then we spotted the hut and saw the men who were waiting for the provisions and fuel we were bringing.

As the plane flew up the glacier it dropped two big bundles of firewood without a parachute. They fell about 700 m from the hut. Then the plane picked up altitude, circled around Revolution Peak at the upper reaches of the Mazardara (the source of the Yazgulem) and back towards the Fedchenko Glacier to drop loaded containers by parachute.

On the first such approach, we made a test drop of one container; on the second and third runs, we dropped five and three at once, respectively. Before the parachutes opened, the containers fell straight down, but because of

our speed (340 km per hour) they seemed to flow back at an angle. In a moment or two, two parachutes opened up over each container, whereupon, swinging gently, they floated down smoothly towards the glacier.

The container drops were made from an altitude of 6,200 m. Since the station itself was at an elevation of 5,000 m, the containers travelled a vertical distance of only 1,200 m. But the flight crew already had the hang of this kind of operation, so the drops were made with much greater accuracy than those during the first flights described in the book, *Drifting Station Above the Clouds.*

After the drop, life at the station went on as before. "Almost daily ... two or three of the men would be gone, and the others would anxiously await their return. Every such trip involved a certain measure of danger; there was always the possibility that whoever went out might suffer frostbite or, even worse, might slip and fall into a crevasse.

"During the winter, temperatures frequently reached —30° to —35°C. The frost itself did not bother the warmly dressed winterers. What was bad, however, was the wind, which made it seem much colder than it was.

"There was always plenty of work to do. Even when there was a snowstorm for several days running and the wind velocity got as high as 30 m/sec, the meteorological observations and snow surveys went on, and, besides, the snow had to be cleared away from the hut and the instruments, coal brought in, etc. But everyone at the winter camp was always in good spirits" [78].

Regardless of complications and difficulties, all observations were made exactly on schedule. In the meantime, the hut kept moving right along with the glacier at a rate of 60 cm a day. One of the ways of measuring the movement was by pegging a number of surveying poles in a straight line across the entire glacier. The poles in the middle gradually moved downstream forming a downward bending arc. After taking the appropriate observations, the men would straighten the pole line again.

Besides the upper station and permanent observatory built on the Fedchenko Glacier in 1932-1933, another station was organised during the IGY at the lower end of the glacier. The basic work there was conducted by hydrologists.

Seismoacoustical, geodetic and phototheodolitic work was also conducted on the glaciers. Seismologists set off explo-

sions and, using seismic sounding techniques, measured the thickness of the glacier. A sounding of 750 m was obtained in the area opposite the upper reaches of the Tanymas. The maximum measurement was 1,000 m in the central part of the glacier.

I. G. Dorofeyev took part in the geodetic and phototheodolitic work. As soon as he learned of the new expedition he came there from Simferopol and, despite the fact that he was 60 years old, traversed the entire glacier from bottom to top, making a new geodetic and phototheodolitic survey.

The results of the studies made on the Fedchenko Glacier during the IGY were published in a special monograph [79]. Among the comprehensive data it contained on the giant glacier, its basin and ancient and modern glaciation was the corroboration of the fact that the 1928 measurement of the glacier's length as 77 kilometres was correct.

Besides the extensive work done on the Fedchenko Glacier during the IGY, substantial geographical discoveries were also made in other regions of the Pamirs. It proved to be especially difficult to study the western part of the Pamirs, with its tremendous heights, deep valley separations, steep gorges and dangerous crossings over swift mountain rivers. In the southern regions of the western Pamirs, as in the northwestern Pamirs, the explorers had also to be skilled mountain climbers.

Some important discoveries were made in the Rushan Range of the Western Pamirs. They were pioneered by a member of the Tajik-Pamir expedition S. I. Klunnikov, a gifted geologist and explorer who was later to die fighting for his country in the Great Patriotic War. The Rushan Range was but one of the many regions he explored in a tremendous area south of the 38th parallel that was known least of all at that time.

Klunnikov's explorations and surveys were responsible for some drastic changes in the then existing picture of the river system and mountain arrangement, and led to important geographical discoveries.

"The southern Pamirs," wrote Klunnikov in 1936, "were until recently almost a solid *terra incognita*. Over a period of several years, I conducted geological explorations in the southern Pamirs and could not, of course, ignore a number of incongruities in the geographical notions that still existed.

"It is part of the geologist's nature to complain about the imperfections of the basic topographical data he is given, but at the same time, there is a certain fascination in the novelty and surprises involved in working in a topographically uncharted area. This interest somewhat compensates for the tedious and tiresome visual surveys that have to be made in such places."

"It turned out," he continued, "that I had more than my share of novelty and surprises. In the course of my work, besides making adjustments in the map, I had the good fortune of discovering a 7,000 metre-high peak, a glacier over 50 sq km in area, two rivers, each over 50 km long, and a number of 'smaller' peaks up to 6,500 m high, glaciers up to 10 km and streams up to 30 km long" [80].

The 7,000 metre-high summit Klunnikov referred to was Patkhor Peak in the Rushan Range. His first glimpse of it was from the left bank of the River Gunt, from which vantage point it was far to the north, standing out distinctly, because of its height, among the crests around it. Once the party had crossed the Gunt and began to go up along the bank of its swift tributary, the Patkhor, "this peak loomed directly ahead of us ... now almost hidden from view as we passed through a valley, now silhouetted in all its beauty against the sky. Huge glaciers could be seen stretching down its slopes, but its crest was almost snowless" [81].

After spending the night in the last small grove, the travellers began their ascent towards the summit. They came upon a huge accumulation of moraine, and from there got an unexpected view of an amphitheatre of névé fields and glaciers, all merging into a single mighty glacier whose tongue, covered with rocks, descended to an elevation of 4,400 m. It was learned that this glacier, with its nine component branches, occupied an area of 50 sq km, and that its biggest tributary was over 10 km long. The glacier was named the Markovsky Glacier in honour of A. P. Markovsky, a member of the Tajik-Pamir expedition, who headed the geological exploration of the Pamirs.

Klunnikov measured the height of the peak. "After calculating the height of the peak by fixes," he wrote, "we found that it ranged between 6,900 and 7,150 m (one fix even gave 7,230 m). In any event, this peak is at least 7,000 m high" [82].

Thus, Klunnikov had discovered the highest peak and the largest glacier in the Rushan Range.

In 1946, a mountain climbing expedition visited the Patkhor Peak area. Members of the expedition climbed to the summit, and, because of the favourable weather, were able to spend about two hours there taking observations and photographing and sketching the surrounding ridges. That expedition also studied the Markovsky Glacier and determined that it had 13 components, not 9, as Klunnikov had reported. The largest tributary was found to be 13 km long, while the length of the whole intricate Markovsky Glacier system from west to east was 25 km, with a total area of about 60 sq km.

One of the summits rising above the glacier near Patkhor Peak was subsequently named Klunnikov Peak by the expedition. One of the glaciers on the northern slopes of the Rushan Range in the Patkhor Peak region was also named after Klunnikov.

Some time later, an instrumental survey of that area showed that Patkhor Peak was considerably smaller than Klunnikov had figured—only 6,080 m, but this did not alter its status as the highest peak in the range.

When we speak of a peak being "only" 6,080 m high, it shows what tremendous elevations exist in the Pamirs. No peak in the Caucasus rises that high, to say nothing of the Alps, whose highest point, Mont Blanc is 4,810 m.

The blank spaces in the Rushan Range still remaining after Klunnikov and others had done their pioneering work were thoroughly explored after the war by geological prospecting teams; this work gave a complete picture of the extent and character of the glaciers and relief features in the area. A total of 260 glaciers have been counted in the Rushan Range, 120 on the south side, and 140 on the north.

Another area explored by Klunnikov's geological detachment of the Tajik-Pamir expedition was the high Shakhdarinsky Range at the far end of the southwestern Pamirs. Old maps showed some high peaks in this region, but they had never been explored and their elevations were unknown.

One of these, which used to be called Empress Maria Peak (6,800 m, according to Klunnikov's measurements), was renamed Engels Peak. "It has massive contours with a tent-like summit, the northern face of which is a two kilometre-high precipice completely barren of snow."

Another, more westerly and even higher peak, once called the Tsar-Mirotvorets Peak, is now known as Marx Peak.

"This is a pyramid-shaped snowy summit situated in a tangled mountain knot near Vrang Pass." Its height, according to Klunnikov, is 7,000 m.

After Klunnikov and other members of the Tajik-Pamir expedition (1932-1936) had done their work, the overall arrangement of the main ranges in the southern Pamirs became clear. Subsequent explorations filled in the details against this background.

In 1946, the same mountain climbing expedition that had climbed Patkhor Peak in Klunnikov's footsteps also worked in the region of Marx and Engels peaks. On Marx Peak, "the altimeters gave a reading of 7,000 m." A diagram of the glacier arrangement in the area was drawn up on the basis of observations made at that time.

Later topographical surveys established that Marx Peak is 6,726 m and Engels Peak, 6,510 m high, i.e., somewhat less than Klunnikov's estimates.

When in 1946 alpinists E. A. Beletsky and E. M. Abalakov after a difficult three-day climb reached the top of Patkhor Peak, a remarkable panorama of mountains opened up before them. They got the impression that some of the peaks in the western part of the Shakhdarinsky Range off in the distance were no smaller than the one they were on. Since Patkhor Peak was then still thought to be 7,000 m high, the prospect of discovering another such giant was enticing. And so the idea was born to organise a new expedition to the southwestern Pamirs, to the peaks in the western part of the Shakhdarinsky Range.

Such an expedition was outfitted in 1947, and explored the region around Mayakovsky Peak (6,096 m) and Berg Peak (6,093 m)* in which the southernmost centre of glaciation in our country is found.

Some of the members of that expedition later stayed on to work with a party that was surveying parts of the southwestern Pamirs. They helped topographers and geodesists place triangulation markers on high peaks.

The new surveys and explorations added considerably to the knowledge about glaciers in the Pamirs. Korzhenevsky's

* The name, Mayakovsky Peak, had already figured in the reports of the Tajik-Pamir expedition and in particular in a book written by Klunnikov in 1936. The height of the peak was considered to be 6,600 m. The name, Berg Peak, was suggested by the expedition of 1947.

catalogue of Central Asian glaciers, published in 1930, listed 278 glaciers in the Pamirs. Today, 1,085 are known to exist there. Most of them, 702 in number, are over 2 km long, and seven are over 20 km long. The Pamirs thus have more large glaciers than any other mountain glacier region in the USSR.

The area of glaciation was formerly registered as 2,470 sq km. But according to calculations made by R. D. Zabirov in the 1950, after accurate phototopographical surveys, it proved, in fact, to be 8,041 sq km, which is almost 11 per cent of the entire surface of the Pamirs. It is estimated that the volume of water contained in the Pamir glaciers is roughly equal to the volume of water in the Aral Sea.

An area of 7,237 sq km of the Pamir glaciers and névé fields belongs to the Amu Darya River basin, feeding the rivers of the basin with its melted snow. Since the rivers of the Amu Darya basin play such an exceptionally important role in the economic life of the Central Asian republics, nourishing the bulk of the oases there, and the Amu Darya itself is navigable and feeds into the Aral Sea, it is clear that an accurate picture of glaciation in the Pamirs is not only of great geographical interest but of great practical importance as well.

The explorations of the Pamirs carried out in Soviet times have revealed their natural resources and, what is very important, they paved the way to making the Pamirs widely accessible. Across the eastern and southern regions of the Pamirs, into which only individual brave travellers had penetrated in the past, there is now a highway connecting the city of Khorog, the centre of the Gorno-Badakhshan Autonomous Region, with Alai, Ferghana and the rest of the Soviet Union. Besides the Osh-Khorog highway, there is now another, called the Bolshoi Pamirsky highway, connecting Khorog with Dushanbe. These two roads and regular air service have radically changed the economic life of the region. Moreover, they facilitate the further investigation of the Pamirs and the development of their natural resources.

CHAPTER 9

FILLING IN THE BLANK SPACES ON THE MAP OF THE CENTRAL ASIAN DESERTS

The natural features of deserts are unusual, unique and, in their own way, severe.

B. A. Fedorovich

The mountains were not the only places in Central Asia that showed up on old maps as blank spaces or were represented inaccurately on the basis of scanty information.

In the very centre of Central Asia, between the Amu Darya and Syr Darya rivers, lies the vast Kyzyl Kum desert, covering an area of 325,000 sq km. Before the revolution, this desert attracted very few explorers and was thus among the least studied parts of Central Asia. People judged the desert by a description of it given in the 1860s by a Hungarian traveller by the name of Á. Vámbéri.

Vámbéri wrote of the fierce winds, similar to the samooms of the Sahara; of the unbearable heat and salty water; of the enormous tracts of sand, with no vegetation cover whatsoever, over which one could travel only by camel. Some parts of Vámbéri's description evoked dread. He spoke of the Adamkrylgan well as of a place in which one must inevitably perish.

"People were accustomed to judging the Kyzyl Kum by the hot west wind that sometimes blows during the summer months in the Ferghana Valley. It begins somewhere in the central part of the Kyzyl Kum, gets heated by the burning hot sand and then, as it blows over the oases, it scorches leaves, grass, green shoots and planted crops.... They also

judged the Kyzyl Kum by the sands that advance to the Bukhara and Karakul oases, step by step covering fields, villages and irrigation ditches."

All this "frightened people away from the Kyzyl Kum and contributed to the fact that it long remained unexplored and unintegrated into the economic life of the country. It was considered desert wasteland in the full sense of the word" [83].

Interest in the desert developed only in Soviet times, when it became the object of a series of expeditions carrying out geological, hydrogeological and special geomorphological explorations.

It turned out that the area of barren shifting sand dunes is not so great. Almost everywhere the sand is held in place by vegetation, and only in the vicinity of wells, where the grassy cover is destroyed by livestock coming to water, are there shifting sands. "The vast areas of drifting sands were figments of Vámbéri's imagination," says desert explorer A. F. Sosedko.

Characteristic features of the Kyzyl Kum desert are the isolated elevations and large depressions in its central and southwestern regions. "Nearly all geographical maps showed both central and southwestern Kyzyl Kum as being nothing but sand. In fact, however, there is little sand there; ridgy sands are found only on the outskirts around oases and along the Amu Darya River" [84].

Efforts to study and develop the desert were hampered by the difficulties of travelling over the sand. In 1932, an expedition under Academician A. E. Fersman made the first attempts to cross the sands lying beyond the settlement of Tamdybulak by car. No one believed then that it could be done. However, the attempt was successful, and soon motor transport became the main means of travel in the desert. A unique "highway" made of saxaul branches was built between the town of Turtkul (then the capital of the Kara-Kalpak ASSR) and Tamdybulak. Today, motor highways cross the desert in several directions.

Comprehensive exploration and study of the desert provided extensive data on its natural resources, topographical relief, subterranean water and vegetation cover. Various mineral resources have been discovered there. The desert has been mapped in detail with the help of aerial photography.

As early as 1931, the economic face of the Kyzyl Kum had already changed radically. State and collective farms of Kara-Kalpakia, Uzbekistan and Kazakhstan began to use the desert pastures. Old wells were restored and new ones built. Saxaul groves were restored, and in certain parts of the territory, on the plateau-like surfaces of its residual hills, the cultivation of wheat and barley began. In other parts, mines began operating.

In the very centre of the desert, at the Tamdybulak spring, the town of Tamdybulak grew up. It has a hospital, a telegraph office, a post office, a bank and a fine school building. A shady park has been laid out around the spring.

The sands of the Kyzyl Kum no longer move towards the Karakul and Bukhara oases. A mighty 120 km long barrier of vegetation has been planted there, forever stopping any further advance of drifting sand.

The author of this book crossed that strip of trees and shrubbery during an expedition to that area in 1958. The density of saxaul and *cherkez* brushwood and the height of the saxaul trees were truly amazing. It was a real forest and something you would never expect to find in a desert!

Large artesian basins have been discovered in the central and southwestern part of the desert. They have become the centres of farming areas, complete with experimental stations whose efforts are directed towards providing additional fodder for livestock. In the south, in Gazli, one of the largest gas deposits in the USSR was discovered and is now being developed. Recently, the Muruntau gold ore deposit was discovered, around which a settlement called Zarafshan (Uzbek for "gold bearing") has already sprung up.

To the northeast of the Syr Darya, beyond the Karatau Range, stretches the Muyun Kum desert. The first Soviet explorations and route surveys of this desert were made by an expedition headed by N. L. Korzhenevsky in 1922.

Later, comprehensive studies were made to determine how best to use and develop this desert along with a number of other regions in Kazakhstan: Muyun Kum desert, the Chu valley, the Betpak Dala desert, and the steppe region of Sary Ark, which is part of the Kazakh hillocky area. In this complex, the Sary Ark steppe plays the role of summer pasturage, Betpak Dala is used for spring and autumn pasturage, while the Chu valley and the Muyun Kum desert are used for winter pasturage.

Extensive work has been done by Kazakh scientists in solving the problem of developing this complex of territories for maximum productivity. They gave a full description of the desert, pointing out the differences in its natural features connected with the fact that the various parts of the desert are at different stages of formation. On this basis, the Muyun Kum desert was divided into districts.

The Betpak Dala was an almost totally unexplored area before the revolution. It was described as "barren and lifeless", by early travellers, and regarded as frightful and sinister. The only human beings to visit it were Kazakh nomads, who drove their herds across the desert in spring and autumn. In the summer it was completely lifeless.

But after the revolution, some scientists from Tashkent decided to cross the Betpak Dala to see if it was indeed as barren as legend would have it. It became an enthusiasts' desert, as desertologist B. A. Fedorovich called it.

Expeditions of the Central Asian University contributed much to the knowledge of its geographical features. As a result of these explorations, a series of works appeared describing the natural conditions of the desert and indicating the possibilities of its development.

One of the enthusiasts of the desert was geographer D. I. Yakovlev, who devoted over 20 years to its study.

Also of interest is the study and development of the Kara Kum desert. Before the revolution it was partially explored by Russian scientists (V. A. Obruchev, V. L. Komarov and others), but the expanses lying on either side of their routes remained blank spaces on the map.

A big part in the study and development of the Kara Kum was played by an expedition under A. E. Fersman and D. I. Shcherbakov (1925), which went into the central region of the desert primarily in search of sulphur. Fersman and Shcherbakov wanted to verify the confusing and often conflicting stories about the riches of the Serniye Bugry (Sulphur Hills) found in the very heart of the desert, 250 km from Ashkhabad. Despite all kinds of warnings, their small caravan went deep into the desert. Other expeditions followed, all in one way or another connected with the task of mining sulphur in the middle of the desert.

In 1929, a small experimental factory began to operate there on a regular basis. It took 38 days for a special caravan to bring the equipment for the factory across the hot

A. E. Fersman and D. I. Shcherbakov

desert sand. Soon large factories took the place of the little one, and industrial life in the middle of the desert was well on its way.

The foundation of a more thorough study of the Kara Kum was laid by the Kara Kum Geographical Expedition of the USSR Academy of Sciences in 1929, in agreement with Turkmenia's People's Commissariat of Agriculture. The expedition's objective was to make a systematic geographical exploration of the entire desert, excluding its southeastern part. Its programme included geodetic and topographical work (establishing a network of astronomical points; route surveys; barometric levelling, that is, determining the elevation at various points with aneroids); geomorphological and geological exploration; hydrogeological prospecting (investigation of the system of wells) and determining the possibilities for livestock raising. In the spring and summer of 1929, the expedition worked in the northeastern and western parts of the Kara Kum. In 1930, it continued its work, concentrating primarily on the study of the Kara Kum's water resources. The Unguz—a chain of depressions in the middle of the Kara Kum desert—was explored, and a map of almost its whole extent was drawn up for the first time. A thorough investigation was made of the system of wells around the Tedjen and Murgab rivers (in the south) and partially in the Amu Darya strip. As a result of the work done, a substantial part of the Kara Kum desert was now well illuminated as far as its general geography was concerned.

Parts of the desert that had remained unstudied after the 1930 expedition were covered by subsequent expeditions, notably the Turkmen Expedition of 1934.

In 1935, a special detachment carried out comprehensive investigations of the central Kara Kum. Its programme included establishing astronomical points for map-making; eye surveys and determination of absolute elevations; geographical and geological exploration; and geobotanical investigation, primarily aimed at determining the fodder resources of the area.

The detachment ran into great difficulties because of the lack of water in the middle of the desert, since many of the wells in the region had been covered over by counter-revolutionary *basmachi* bands during the first years of the revolution.

At one point, the detachment made a two-day trek to one of the wells in the hope of finding water. But they found none; the dry funnel of the caved-in well was overgrown with camel thorn. Forty-six kilometres further on there were another three wells, but they too were empty.

"The forty-six kilometres of the return trip seemed twice as long. The men's throats were parched, their bodies ached, and their heads throbbed from heat and exhaustion. The desolate sandy plain seemed endless" [85].

To save themselves and the horses, the explorers had to clean out the filled-in well, lowering themselves by rope and pulley down the twenty-metre deep shaft.... The pulley creaked under the strain as the camel kept pulling out sack after heavy sack of wet sand and mud.... By the following day the well was restored and gave water to the party. They could now continue with the work they set out to do.

It was not long before airplanes began to be used extensively in the exploration of the Kara Kum. The use of aerial photographs made it possible to represent the entire area of the desert on the map and thus to eliminate the last blank spaces that remained between the lines of the many route surveys made earlier by ground expeditions. The overall result was not only an accurate picture of the natural conditions of the Kara Kum desert, but the development of more efficient and productive pasturing schedules by district, which not only meet the needs of the animals but serve to enrich the pastures themselves.

The explorations carried out in the Kara Kum and neighbouring desert regions thus provided a sound scientific basis for their fuller economic development.

The results of the hydrological and hydrogeological study of the Kara Kum were of particular value for the desert's development. The Geographical Society of the USSR awarded the Przhevalsky Gold Medal to the outstanding explorer of the Kara Kum, V. N. Kunin, for his work, *The Local Waters of the Desert* [86].

New geological explorations in the Kara Kum have led to the discovery of large gas deposits in the Serniye Bugry area and in the south-east (Darvaza, Bairam Ali). Gas and oil have also been found in other places.

Before long, this vast desert region will not only have been studied in depth, but will be in large part transformed. The beginning has been made: a canal in the southern part

of the Kara Kum desert from the Amu Darya to the Mary oasis at the lower reaches of the Murgab River, and then on to the Tedjen oasis and to Ashkhabad and from there along the Kopetdag in a north-westerly direction.

* * *

Explorations carried out in the Soviet period have revealed not only the highest points in the Soviet Union (Communism Peak and Pobeda Peak), but also the deepest depressions.

Pre-revolutionary maps showed the deepest to be the Sarykamysh Depression (—44.7 m), situated along the border of today's Turkmen SSR between the Aral Sea and the Kara Bogaz Gol Bay. It is true that as early as 1914, depressions of about —50 m were discovered in the northwestern part of the Turkmen Kara Kum desert, and in 1917, data was published regarding the Kashkarata (—45 m) and Karagiye (—85 m) depressions in the southern part of the Mangyshlak Peninsula. This information, however, did not come in time to be reflected on pre-revolutionary maps.

The depth of the Karagiye Depression was checked again in 1929, and it was found to be deeper than reported earlier; its bottom measured 106 to 112 m below sea level. But even that was not the final word. Instrumental levelling carried out in 1935 gave a reading of —129.6 m, and even this was not in the deepest part where there is a salt-marsh that was impossible to penetrate. Today's maps show —132 m as the maximum depth of the depression.

The Karagiye Depression (the name means "black mouth") contains the lowest point in the USSR and is one of the deepest depressions in the world.*

In 1935, E. M. Murzayev discovered the second deepest depression in the USSR, namely the southern depression of the Akchakai near the Ishek Ankren Kyr Plateau in the northwestern part of the Kara Kum desert.

Prior to Murzayev's exploration that region was still a blank space on the map. It was known that there were deep, dry cavities in the vicinity of the small plateau known as Ishek Ankren Kyr (which in translation means "the plateau

* The lowest depressions in the world are the Dead Sea (in the western part of the Arabian Peninsula), with a depth of —392 m; the Turfan Depression in central Asia, at —154 m; and the Kattara Depression in Egypt, in the Lybian Desert, at —133 m.

of the braying donkey", a curious name but without geographical meaning). There was no detailed information about these cavities, so it was decided to explore them and put them on the map.

Crossing the monotonous surface of the desert plateau, in places covered with sand, saxaul bushes and wormwood, Murzayev's party came to a scarp, at the bottom of which was a huge depression. They determined that it lay 22 m below sea level.

On the next day, they found another depression, even bigger than the first. The scarp of the Ishek Ankren Kyr Plateau dropped down in beautiful steps and formed a kind of amphitheatre around the depression, which was about six kilometres wide.

When they descended to the bottom and checked their barometric altimeter they couldn't believe their eyes; they found that they were 100 m below sea level. Other instrument corroborated this reading. "When I completed my final calculations in Leningrad," Murzayev wrote, "it turned out that the bottom of the depression is 92 m* below sea level" [87].

Several other depressions of 45 to 55 m in depth have been discovered, besides the Karagiye and Akchakai depressions. The Sarykamysh Depression ended up in sixth place.

* * *

A comprehensive and detailed study has been made of the Ustyurt desert plateau and the Mangyshlak upland, where oil and gas deposits of industrial value have been discovered. The team of geologists who discovered and prospected the oil- and gas-bearing provinces of Mangyshlak were awarded the Lenin Prize (1966).

Detailed geographical and geological studies have been made of the desert regions north of the Aral Sea. An exceptionally big contribution in this regard was made by Academician A. L. Yanshin, who published an excellent monograph summarising extensive data on the geological structure and paleogeography of the region [88].

The map of the Aral Sea has seen some changes. For example, many points along the coast have had to be "moved"

* The latest maps show a depth of 81 m.

(up to six minutes latitude and 12 minutes longitude). Numerous soundings made by Soviet expeditions have substantially augmented our knowledge of the bottom depths.

Lake Balkhash and other lakes in the deserts of Central Asia are now also more accurately represented on the map.

* * *

Soviet geographers have great accomplishments to their credit in the scientific study of the relief of the Central Asian deserts. Academician L. S. Berg, for example, produced a summary work on the relief of Turkmenia and all of Central Asia, and Academician I. P. Gerasimov made an analysis of the history of the development of the relief of the Central Asian deserts.

A big contribution was made by B. A. Fedorovich, who made extensive use of air observation and aerial photography in studying the relief forms of the deserts. His work was of great practical significance in that it was instrumental in determining the proper pasturing schedules for the various regions of the Kara Kum desert.

V. A. Paletsky, V. A. Dubyansky and M. P. Petrov and other explorers studied the drifting sands of the desert and put in much time and effort to develop methods of holding them in place or diverting the drift in more desirable directions.

The entire area of the Central Asian deserts is now represented on the geographical map accurately and in detail. The natural conditions of the deserts have been extensively studied. Their development is now in full swing.

CHAPTER 10

CHANGES IN THE MAP OF THE CAUCASUS AND THE EUROPEAN PART OF THE USSR

Only people who have a deep love of nature and are not afraid of hardships feel at ease in an expedition, and their work is full of unfeigned enthusiasm. They are able to see real beauty; they can readily recognise the treasures hidden in the bowels of the Earth; they cannot easily be led astray; they will be able to find pleasure in a difficult march, or in a night thunderstorm or in the rumble of a landslide.

G. A. Fedoseyev

As a result of topographical work carried out in the Caucasus, the heights of many peaks in the Caucasus mountains have been accurately determined and a more precise picture of the relief has been produced.

Numerous explorations, both scientific and by mountain climbers, have been made in Soviet times of the peaks and glaciers in the Caucasus. New names of peaks have appeared on the map.

Despite the fact that the Caucasus mountains had been explored long ago and a large-scale topographical survey of the Caucasus had already been made, refinements in the cartographic representation of certain areas were still needed.

A great deal of valuable information has been gathered by numerous Soviet expeditions studying the geological structure, relief, climate, water resources, topsoil and vegetative ground cover in the Caucasus.

From the standpoint of geology, the Caucasus is now regarded as one of the most thoroughly studied regions of the world, despite the great complexity of its geological structure. A number of works have been written by geographers and naturalists on the relief and natural conditions of the Caucasus.

Of great scientific and practical interest have been studies made in Soviet times of glaciers in the Caucasus. Special

mention should be made of the expeditions of the Second International Polar Year and of the International Geophysical Year. Geographers from the universities of Moscow and Kharkov played a big part in the IGY programme of glacial exploration in the Caucasus, as a result of which the exact area of glaciation was determined and the dynamics of the glaciers there studied in detail. The geographers from Kharkov published several volumes of *Materials of the Caucasian Expedition* (*1960-1965*), containing articles reporting on the exploration of ancient and modern glaciation in that area.

The Moscow geographers, under G. K. Tushinsky, conducted a detailed studies on Mt. Elbrus and completed an atlas of its glaciers.

As concerns the study of individual geographical features, especially noteworthy was the comprehensive investigation on Lake Sevan. This large mountain lake is now one of the most thoroughly studied lakes in the world, especially from a hydrological point of view. A detailed chart of its depths has been drawn, and the lake's hydrological regime has been determined. The result of many studies made over the years was published in the early 1930s in the form of 17 special editions in a series entitled *Materials on the Study of Lake Sevan and Its Basin.*

Karstologists and speleologists* have studied the stalactite caves and deep karst abysses of Caucasia, especially in the western half of the southern slope of the Caucasus mountains. In the Bzyb range the Snezhnaya pit has been discovered. This is one of the deepest abysses in the USSR (now the second) with a depth of more than 680 m (an even deeper abyss was recently discovered on the Kyrktau Plateau in the western part of the Zeravshan Range in Central Asia). Georgian speleologists discovered the Novy Afon Caves, containing huge halls, which have already been equipped for tourist tours.

Deep natural shafts (up to 500 m deep) and stalactite caves have also been examined in the mountains of the Crimea. The Red Caves system has been explored to a dis-

* A karstologist is a specialist in the study of karst phenomena, which occur in areas of water-soluble rock, such as limestone, dolomite, gypsum, rock-salt, etc., and where the terrain is characterised by barren rocky ground, underground caverns, etc. Caves, which are studied by speleologists, are also related to these phenomena.

Y. M. Shokalsky

tance of over 13 km. In total length, this is the fifth largest cave of any kind and the largest limestone cave in the Soviet Union.

* * *

Comprehensive studies of the Black and Caspian seas have been made in Soviet years.

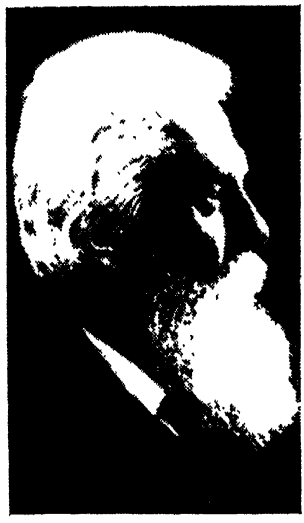
An extensive study of the Black Sea was conducted between 1924 and 1927, under the famed geographer and oceanologist, Y. M. Shokalsky.

Studies of the Black Sea have been conducted by a number of scientific establishments (the Sevastopol, Karadag and Novorossiisk biological stations, the Azov and Black Sea Institute of Fishing in Kerch, and others) which have investigated its hydrological regime, its biology and fish life. The depths of the sea have been checked and the map representation of its bottom relief has been corrected in places. The overall picture of depths has remained the same as before, but some substantial changes had to be made in regard to details of the bottom relief. Great advances have been made in tracing the geological history of the Black Sea (by academicians A.D.Arkhangelsky, N. M. Strakhov, and M. V. Muratov).

In the last 20 years, the research vessels, the *Vityaz* and *Mikhail Lomonosov*, have taken part in the hydrological studies of the Black Sea (they have worked there in between their long ocean expeditions). An expedition on the *Mikhail Lomonosov* gathered important data on the dynamics of deep water and on deep-water currents. The shores of the sea, the movement of shore alluviums and the structure of the sea bottom have been studied in detail. It has been determined that the Black Sea basin has an oceanic type of the Earth's crust.

As regards the Caspian Sea, a hydrological expedition, under V. V. Valedinsky and B. A. Apollov, worked in its northern part as early as 1918.

In 1934, the Institute of Fishing and Oceanography organised a large comprehensive oceanographic expedition, headed by S. V. Bruyevich, to explore and study the Caspian. Later, studies of the Caspian were conducted by a special Caspian Commission of the USSR Academy of Sciences. The Commission was headed by N. M. Knipovich. At the present, among the institutions conducting systematic studies of the Caspian are the Institute of Oceanology of the USSR Academy of Sciences, with a special Caspian Sea department; the State Institute of Oceanography; the All-Union Institute of Fishing and Oceanography; the Institute of Geography of the Academy of Sciences of the Azerbaijan SSR and the Moscow State University. Extensive soundings have been made, resulting in significant changes in the picture of the bottom relief. The continental shelf in the Caspian has been examined in greater detail than that in any other sea. Detailed geological charts now exist of the shelf in Daghestan, northern Azerbaijan, the Apsheron Peninsula and the Baku Archipelago, where exploration has been carried out for the purpose of studying the oil-bearing structure of the sea bottom. In the course of the many studies conducted, the submarine rise of Cape Peschany, the northern and southern depressions in the mid-Caspian, and various other submarine rises, canyons and valleys were discovered. In the southern section of the sea, a number of submarine ridges were discovered, the largest of which are the Abikh and Shatsky ridges (named after eminent geologists). The contours of the southern basin of the Caspian have been more precisely determined and the fact that it has an oceanic type of the Earth's crust has been ascertained. Soviet geologists have thrown light on many complex problems of



N. M. Knipovich

the geological history of the sea. The shores and the natural conditions of their formation have also been subjected to thorough study.

Soviet hydrobiologists have not only studied the fauna of the Caspian Sea, but have taken effective measures to enrich the sea with new species to serve as a source of food for the commercially valuable Caspian sturgeon. About 50 per cent, and in some parts of the sea up to 90 per cent, of the sturgeon feed on these "bio-transplants". A large part of the credit for this study and transformation of the Caspian fauna belongs to Lenin Prize winner Academician L. A. Zenkevich.

* * *

Important geographical discoveries have been made by Soviet explorers in the Northern and Polar Urals. They determined that the highest point in the Ural mountains is Mt. Narodnaya (1,894 m). Other peaks discovered in the region also turned out to be higher than Mt. Telpos-Iz (1,617 m), once thought to be the highest mountain in the Urals.

One of the first Soviet expeditions to the Urals was the 1924 Northern Urals Expedition of the Academy of Sciences. The man who initiated the expedition, B. N. Gorodkov, was to write: "It was an intriguing challenge to undertake the exploration of a vast territory that was still a blank space on the map of the Northern Urals, a region of especially difficult accessibility" [89].

The expedition worked for several years in a row, from 1924 through 1928, covering a vast area in the Northern, Transpolar and Polar Urals and even taking in the edge of the West Siberian Plain as far as the Ob valley. Important geographical discoveries were made in the fourth year of the expedition's work (1927): the highest peaks in the Urals—Mt. Narodnaya and Karpinsky Peak—were discovered at the upper reaches of the Naroda River.

A number of ridges and plateaus in the Transpolar Urals were differentiated and named, and in both the Transpolar and Polar Urals a large number of small glaciers were discovered that were never before known to exist.

In the mid-19th century, E. Hoffman, a well-known explorer of the Urals, wrote that "there is not a single glacier in the entire range". However, in 1929, A. N. Aleshkov discovered glaciers on the eastern slope of Mt. Sablya, and by

1949, 27 glaciers were known to exist in the Transpolar Urals. Glaciers were likewise discovered in the Polar Urals, where they are as big as 2.5 km in length and 1.5 sq km in area (the Institute of Geography Glacier).

A total of 142 glaciers are now known in the Urals. All of them are relatively small, so that the total area of glaciation is only 25 sq km, and the total volume of ice about one cubic kilometre. Nonetheless, the discovery of glaciers in the Urals is of considerable scientific interest.

Important practical results have come of the comprehensive study of the Urals, especially of their geological structure and relief. Such explorations were instrumental in the development of the mining industry in that region.

* * *

Great success has been achieved in Soviet times in studying the Kola Peninsula. Exploration of this interesting region was conducted at the initiative of S. M. Kirov.

Explorations carried out under A. E. Fersman revealed large deposits of various minerals on the peninsula, which has since become a major mining region.

In 1921 geomorphological explorations on the peninsula began, and G. D. Richter wrote a summary work on its relief [90]. Later, somewhat more detailed explorations were carried out, and in the Khibiny Mountains some small glaciers were found.

From new surveys of the vast Russian Plain, elevations in a number of regions, especially in the north, were ascertained with greater precision. For example, while Pot-Churk (324 m) had long been considered the highest point of the Timan Ridge, present maps show that Chetlassky Rock has an elevation of 463 m.

The most amazing fact was the discovery of a new range north of the Russian Plain, the Vetreny Poyas, stretching along the southern shore of the Onega Gulf of the White Sea.

In pre-revolutionary times, this region was one of the least studied parts of European Russia. There were no accurate maps of it, no data on elevations, nor any correct geographical data. The region was difficult to access, roadless and unpopulated.

The old name, Vetreny Poyas, which means "wind belt", was given to the ridge by the people who inhabited the sea

coast (*pomori*). It lies only 30 to 40 km inland and is easily visible from the sea. "Being an open ridge facing the sea it naturally seemed to the *pomori* to be always windblown, hence such a strange-sounding name" [91]. The name became deeply rooted with the indigenous population, especially among the coastal dwellers.

However, the name Vetreny Poyas never appeared on any map, and there was no reliable information as to its height. The range was lost among the dense forests stretching along the Onega Gulf. The first very incomplete, and even incorrect, data were provided in the 1870s by geologist A. A. Inostrantsev, who had not visited the range himself, however, but simply described it briefly according to information given him by local inhabitants. The first explorations of various parts of the range took place in Soviet times. Information was gradually accumulated between 1921 and 1935, but even then geographers did not have a full picture of it.

In 1937, M. N. Karbasnikov, a geographer from Leningrad, concentrated his field observations exclusively on Vetreny Poyas, and it was his work that provided the basic materials for a full geographic description of the range. After that, the name Vetreny Poyas began appearing on all new maps.

All former maps showed only the hydrographic network of the region, with nothing to characterise the relief. In other words, the mountain range was not indicated. Finally, Karbasnikov drew up a hypsometric map on which the mountain range stood out sharply, especially its high northern scrap facing the flat marshy plain of the Pomorsky coast. It was found that the overall length of the range was about 250 km and that many of its peaks were higher than 300 m above sea level. The highest point in the Vetreny Poyas Range, the Bolshaya Lev-Gora (Big Lion Mountain) has an elevation of 350 m, according to Karbasnikov. Almost the same elevation is marked on current maps—336 m.

There is a beautiful view from atop the summits of the range. All around are boundless forests, rising over hills and dropping down into deep valleys. It seems as though all the peaks in the range are standing in a long row running northwest to south-east. On a clear day, the White Sea can be seen from the highest points.

Vetreny Poyas has now become relatively easy of access, because a new railroad has been built connecting Arkhangelsk and Belomorsk.

Over the years since the revolution, the great tundra expanses in the northeastern part of the Russian Plain have been studied extensively. In 1921, comprehensive explorations in the Bolshezemelskaya tundra were carried out by Academician A. A. Grigoryev, a pioneer in the study of the East European Subarctic.

In the central and southern parts of the Russian Plain, which had been relatively more densely settled and had been studied and mapped much earlier than other parts, Soviet surveys and explorations naturally resulted only in some refinements being made in the cartographic representation of the relief and hydrographic network. However, if we compare present-day hypsometric maps with those existing before the revolution, we will find differences, sometimes quite substantial, in topographical relief details.

The map representation of many of the lakes in the Russian Plain has changed considerably. Some of these lakes have been subjected to thorough study. Take Lake Ilmen, for example. As a result of many years of careful study in connection with the construction of the Volkhov Hydroelectric Station, this lake in the 1920s had already become one of the most extensively studied lakes in the USSR. Atlases of the lake were published between 1925 and 1927.

There is no longer any possibility that unexpected discoveries might be made on the Earth's surface in the Russian Plain. But below the surface there are still many secrets. Only recently, the largest karst caves in the USSR were discovered in Podolia, in the southwestern sector of the Russian Plain. Optimisticheskaya Cave has a total length of 109 km; Ozernaya Cave, 105 km; Kristalnaya Cave, about 19 km; Mlynki Cave, 14 km. In total length of passageways and caverns, Optimisticheskaya Cave ranks third in the world and Ozernaya Cave is the fourth. All of the above-named caves are the largest gypsum caves in the world.

As concerns the scientific study of the entire geography of the Russian Plain, there were many gaps left in pre-revolutionary times. Eminent Russian geographer D. N. Anuchin wrote that in pre-revolutionary Russia not only the outlying regions were poorly studied, but "there are a great many gaps in the geography of the more central and seemingly better known parts of our country" [92].

Great advances have been made in this regard in Soviet times. Studies have been made of the relief of regions that

had undergone glaciation in the Quaternary Period. Especially great contributions to this study (primarily of the northwestern and central parts of the Russian Plain) were made by A. A. Borzov, K. K. Markov and A. I. Spiridonov. The extent to which glaciation had occurred has been determined, albeit perhaps not completely.

Extensive work has been done in the study of erosional forms of relief—valleys and gullies. Explorations carried out in the Ukraine, the Central Russian Highland, along the Volga, and beyond the Volga have changed our understanding of the nature and distribution of ravines, which in many areas are a great detriment to agriculture. Measures to combat gully erosion have been and are being studied. For various practical reasons, karst forms of relief, etc., have also been studied.

Summary works have been produced on the relief of the Russian Plain. The relationship between relief and river networks on the one hand, and the tectonic structure and the latest tectonic movements, on the other, have been determined. Geological, hydrological, soil and geobotanical studies of the region have been made. F. N. Milkov, N. A. Solntsev and other geographers have studied the landscape in various regions of the Russian Plain and have given generalised descriptions of its complex physiography. Our knowledge of the natural conditions of the Russian Plain has become incomparably fuller and more accurate. Deposits of coal, oil, gas, various chemical raw materials, and iron, manganese and other ores have been discovered there. The boundaries of many of the former mineral mining regions, such as the Donets Basin, have been enlarged.

* * *

We have seen how as a result of Soviet explorations the face of the geographical map of the USSR has changed and how great many of the changes have been. Blank spaces have been filled in not only on the topographical and general geographical maps, but also on specialised maps, such as those dealing with geology, soil, etc. In this respect there is still much work to do, but what has already been accomplished in Soviet times has gone far, far beyond the results of research in the pre-revolutionary period, and, most importantly, provides the scientific foundation for developing and transforming the territory of the Soviet Union.

EXPLORATIONS AND DISCOVERIES OUTSIDE THE SOVIET UNION

CHAPTER 11

IN FOREIGN COUNTRIES OF VARIOUS CONTINENTS

An expedition! This word is full of complex and varied meanings: the joy of discovery and the bitterness of disappointment, the heat of the desert and fierce mountain winds, the ice of polar regions and the salty odour of sea water, the romance of travel and new encounters along endless roads....

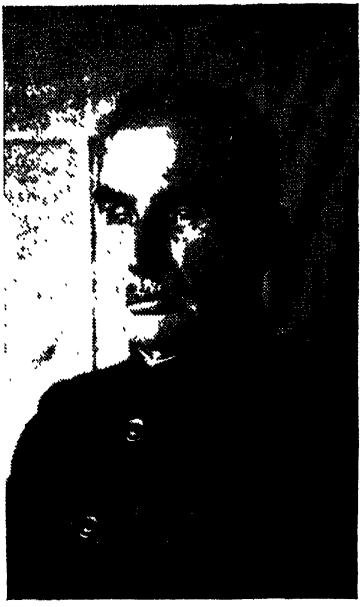
E. M. Murzayev

Soviet scientists have carried out important explorations not only within the Soviet Union, but in foreign countries, as well. They have produced especially notable results in central Asia—in the Mongolian People's Republic and Western China. There, Soviet scientists discovered an entirely new and unique world of nature.

In the 19th century, a big contribution to the study of central Asia was made by the courageous Russian traveller N. M. Przhevalsky and his associates, students and followers. Soviet expeditions carried on the fine traditions they established.

One of the first large Soviet expeditions to work in a foreign country was the 1923-1926 central Asian expedition of the State Russian Geographical Society. The expedition was headed by P. K. Kozlov.

Kozlov was a student of Przhevalsky's and one of his companions in the fourth central Asian expedition. He also took part in expeditions to central Asia under M. V. Pevtsov and V. I. Roborovsky. All this had taken place in the 19th century. At the turn of the century (1899-1901, 1907-1909) he himself headed expeditions of the Russian Geographical Society to central Asia, during which he won fame for discovering in Central Mongolia the ruins of the dead city of Kara



P. K. Kozlov

Khoto, the ancient capital of the Tangut kingdom of the Hsi-Hsia tribe.

Thus, the 1923-1926 expedition into central Asia was the sixth such journey for Przhevalsky's worthy successor, Kozlov. Due to Kozlov's participation, the 1923-1926 expedition was the connecting link, as it were, between the central Asian explorations in Przhevalsky's epoch (reference here is to the pre-revolutionary travels not only of Przhevalsky himself, but also of his students and followers) and the new explorations in the Soviet period.

Among the personnel in Kozlov's expedition were botanists, zoologists and geographers—N. V. Pavlov, E. V. Kozlova, S. A. Kondratyev and others. Incidentally, Kondratyev was basically a composer by profession. He wrote down the melodies of Mongolian folk music as he went along, but at the same time proved himself to be an outstanding naturalist and did an excellent job of conducting archaeological excavations. The expedition explored certain areas of Northern Mongolia and the Gobi desert. In the Gobi the travellers dropped down south as far as the ruins of Kara Khoto. They gathered rich natural historical (zoological, etc.) and archaeological collections.

In the Tola River basin, members of the expedition unearthed a huge granite sculpture of a tortoise weighing about one and a half tons, and not far from that find they discovered images of people carved in stone. The local Mongolian inhabitants had no idea of the origin or significance of these stone figures and regarded them with superstitious fear. The explorers also came across figures swathed in silk fabric. The mouths of such figures were usually smeared with porridge: the inhabitants would "feed" them to ward off their evil spells. Valuable archaeological materials were

found in burial mounds in the Noin Ula mountain group in Northern Mongolia (the Selenge River basin), and also during the second round of excavations in Kara Khoto. Important paleontological finds were made in the northern part of the Gobi, at a site near Kholt.

The zoological material collected by the expedition consisted of 600 specimen (60 species) of mammals, 2,000 specimen (300 species) of birds, a large number of nests with eggs, 100 species of amphibia, and a huge number (up to 30,000 specimen) of insects, among which were many new species. Kozlov kept a journal in which he recorded many interesting observations regarding the rich animal life in Mongolia [93].

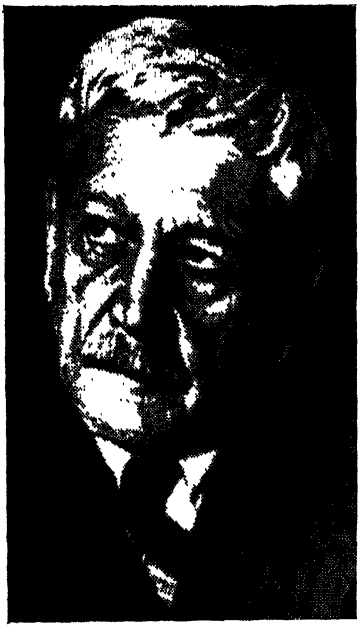
The expedition carried out studies of lakes in Mongolia and gathered geographical data on regions of the Han-hai, the Gobi Altai and the Gobi.

Kozlov's 1923-1926 expedition marked the beginning of a systematic scientific study of the Mongolian People's Republic. Kozlov established close contacts between Soviet researchers and the Committee of Sciences of Mongolia, an honorary member of which he himself became in 1924.

The expedition's personnel helped the Committee, giving advice and taking a direct part in developing certain themes.

In 1925, the Soviet of People's Commissars set up a special commission for the study of Mongolia and Tuva (after 1927, this commission came under the Academy of Sciences of the USSR). Many eminent geographers, botanists, soil experts, geologists, archaeologists and ethnographers took part in the expeditions of the commission. Among them were soil expert B. B. Polynov, botanist-geographers I. M. Krasheninnikov, and N. V. Pavlov, and zoogeographers A. N. Formozov and A. Y. Tugarinov. Actually, several expeditions worked simultaneously in each of the following fields: geography, soil science, geochemistry, geology, archaeology and ethnography. Their reports were published in a special publication of the Commission of the Soviet of People's Commissars of the USSR on the Scientific Study of the Mongolian and Tuvinian Republics [94]. Of especially great interest from the point of view of a geographical description of Mongolia was the work done by B. B. Polynov in the fields of soil geography and physical geography.

In the years that followed, many more large-scale and comprehensive explorations of Mongolia were carried out by



B. B. Polynov

Soviet scientists. By way of example, we will mention only a few of the expeditions in which Soviet scientists and specialists took part.

From 1940 to 1943, an expedition to study the haymaking and pasturage potential in Mongolia was organised by the Committee of Sciences of the Mongolian People's Republic and the All-Union Committee on Forage (USSR). Soviet botanists I. A. Tsatsenkin and A. A. Yunatov took part in this expedition which travelled extensively trhoughout the eastern part of the Gobi studying the vegetation and the forage and grazing resources of the region.

In the summer of 1943, the Committee of Sciences of the Mongolian People's Republic and the Mongolian State University organised an expedition into one of the most remote regions of Mongolia, the Transaltai Gobi, which lies south of the Mongolian and Gobi Altai. Travelling partly by motor car and partly on foot and by camel, the expedition traversed a total distance of 3,760 km within the bounds of 42°15′ to 45°N and 96° to 100°E in what was a typically central Asian desert area. On the basis of the work of this expedition, Soviet geographer E. M. Murzayev and biologists A. G. Bannikov and A. A. Yunatov gave a physiographical and biogeographical description of the Transaltai Gobi.

The largest expedition after that was the 1947-1952 Mongolian Agricultural Expedition of the USSR Academy of Sciences, which worked jointly with the Committee of Sciences of the MPR in a study of the country's natural resources and agricultural production. The scientific personnel in the expedition came primarily from the Academy of Sciences of the USSR. Scientists from the Committee of Sciences of the MPR also took part.

Between 1947 and 1950, the expedition consisted of four teams, one each in the fields of hydrology, botany (forage), animal husbandry and economics. In 1950-1951, a team on plant-growing was organised; it also included soil scientists and climatologists. A forestry team worked for a short time (1950), and in 1950 and 1951, volcanological and geological explorations were also conducted. Thus, the expedition was, in effect, a comprehensive one.

Taking part in the work of the expedition were geologist V. M. Sinitsyn; volcanologist V. I. Vlodavets; geomorphologist and soil scientist I. P. Gerasimov, who studied the features of the relief and soil in all the basic regions of the country and traced the history of the formation of its geographical features; soil scientist N. D. Bespalov; hydrologist N. T. Kuznetsov, who was the first to conduct a study of all the major rivers in Mongolia; botanists, geobotanists, experts on plant-growing, zootechnicians, helminthologists, hydrologists, hydrotechnicians, economists and economic geographers. The basic regions of Mongolia were fully covered by the expedition's various detachments.

The following are some of the results of the expedition's work. The country was broken down into geomorphological regions. The geological structure of the southern and south-western parts of the Mongolian Gobi were studied. Data were collected and a general description compiled on the climate of the country. Data were gathered on subterranian water resources and the system of artesian wells; rivers and river basins were investigated; hydrometric stations were set up on several rivers, and areas in river valleys suitable for irrigation were singled out. The study of ground cover in the country was continued and a soil map of the entire country was drawn up. A study was made of the forests, pastures and hayfields; the distribution of vegetation in relation to relief, soil, etc., was determined and maps drawn up showing types of vegetation, pasture land and natural regions. A natural economic districting of aimaks was worked out. Agricultural studies were made on farming, animal husbandry and agricultural economics.

A four-volume report on the expedition was completed in 1952. One volume consisted of an atlas with numerous maps. Many of the basic parts of the report were published as separate monographs or articles. In aggregate, these monographs are "a kind of encyclopaedia on the natural conditions and

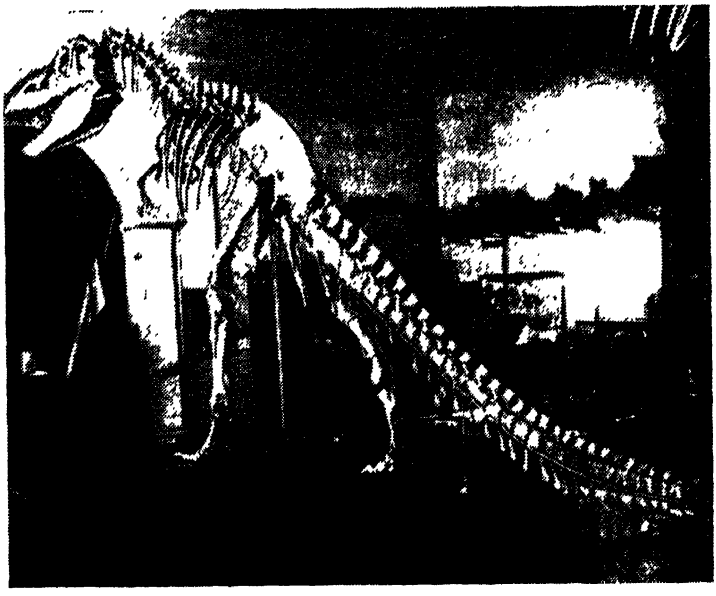
agricultural production of the Mongolian People's Republic" [95].

Mention should also be made of the work done in Mongolia by a number of large paleontological expeditions of the Academy of Sciences of the USSR. Although they were not geographical expeditions in the strict sense of the word they did introduce some considerable changes in our understanding of the history of the development of the geographical environment of central Asia.

The first such expedition, a fairly small one serving the purpose primarily of reconnaissance, was organised in 1946 and headed by I. A. Yefremov, who also led the expedition that followed. In the course of two months of field work, the first expedition covered two long routes in the Southern and Eastern Gobi. Many of the members of that expedition also worked in the 1947-1948 and 1949 expeditions.

In the Nemegetin hollow in the midst of the sands of the Southern Gobi, the paleontologists discovered a whole cemetery, as it were, of large dinosaurs of the Cretaceous Period and some ancient mammals. The dinosaurs and most of the mammals belonged to species never before known to science. In Altan-Teeli in Western Mongolia, they found a place with Pliocene mammals; there, "sticking out of the top of every hill were skulls and other skeletal parts of late Tertiary mammals: horned hylothereria, three-toed hipparions, giraffes, beasts of prey and other animals" [96]. The Nemegetin group of dinosaur locations and the Pliocene mammal location in Altan-Teeli turned out to be among the largest in the Old World. Moreover, there were many other finds of ancient vertebrates scattered about in the Gobi desert in the southern and western outskirts of the country. The expeditions gathered an enormous quantity of varied and excellently preserved materials (460 huge crates weighing over 120 tons).

To unearth and transport the remains of extinct monsters and to put them into the service of science was not an easy task. "The excavation of dinosaurs, these giants of the Earth's past history," wrote I. A. Yefremov, "can be compared to a serious industrial undertaking, like the mining of ore or other minerals. The 'medium-sized' dinosaur skeletons are 15 to 16 metres long and weigh several tons. The largest dinosaurs—the Sauropods, the remains of which were also found by the expedition—are as big as 25 metres in length and their skeletons weigh several tens of tons.



Skeleton of a carnosaur

"If we add the fact that cleaning the earth and clay from the skeletons is so labour consuming that it takes years and that therefore the skeleton has to be taken from the excavation site right along with the earth packed around it, after first breaking it up into huge blocks, then it becomes clear that the excavation of dinosaurs is an even more complicated process than, say, ore mining.

"Indeed, the bones have not only to be removed from the ground, but removed intact, in the form of massive blocks of enormous weight. Then the blocks have to be moved a distance of 1,000 kilometres over the difficult, roadless terrain of the Gobi desert to the nearest railroad. Not only does a large contingent of workers and researchers have to be brought to the Gobi and be provided with everything they need, but delivery has to be made to the arid Gobi depressions of the large quantities of lumber, plaster, water and fuel necessary for carrying out the excavations and packing the collection unearthed..." [97].

The materials gathered by the expeditions are now almost completely reconstructed and are on display in the Paleontological Museum of the USSR Academy of Sciences and in

the Central Museum of the Mongolian People's Republic in Ulan Bator.

Of what paleogeographic significance are these finds? What new information do they convey regarding the history of the development of central Asian geography?

In the 1920s, some American paleontologists conducted explorations in central Asia (P. K. Kozlov met the head of the American expedition, R. Andrews, in Mongolia during the 1923-1926 expedition). They came to the conclusion that in the Mesozoic Era, the territory of what is now central Asia was the same as it is now—desert country with sparse vegetation and meagre fauna. However, the finds made by Soviet explorers pointed to the widespread past existence there of large numbers of reptiles (dinosaurs) and mammals. This would refute the supposition regarding desert conditions, inasmuch as abundant and constantly available plant life must have existed for the giant animals. It therefore had to be assumed, contrary to the views of the American scientists, that central Asia in the Cretaceous Period was a marshy lowland with abundant water and rich in vegetation. The explorations and excavations that followed fully corroborated this assumption. Species of herbivorous, carnivorous and testaceous animals were found in the "cemeteries" of the huge dinosaurs. Many turtles and crocodiles were discovered, as well as large "cemeteries" of ancient swamp mammals that lived in Tertiary Period. Among the Cretaceous dinosaurs were species of giant Sauropod who inhabited the coastal areas. Mollusk shells and large sea tortoises were also found. Thus, in the area of present-day Mongolia there was in Cretaceous and post-Cretaceous periods not a desert, but an enormous marshy lowland located in the immediate vicinity of a sea. Almost everywhere there are the remains of swamp forests. All this constitutes a geographical discovery of a paleogeographical nature.

Soviet geologists took part in studying the traces of a tremendous earthquake that occurred in Mongolia, in the Gobi Altai, on December 4, 1957. The quake resulted in a series of cracks and fractures in the Earth's crust in the Gobi Altai mountain system, in places accompanied by substantial dislocations of neighbouring tracts of land. Geologists made a seismic study of the entire area.

The results of Soviet explorations conducted in Mongolia prior to the 1950s were used extensively by geographer

Murzayev in compiling his State Prize-winning physiographic description of the Mongolian People's Republic, the first thorough and comprehensive description of the natural conditions of the country ever to be written. Murzayev, a well-known geographer, traveller and expert on the geography of the Central Asian Soviet republics and Mongolia, travelled extensively throughout Mongolia himself (1940-1944) and shared his vivid impressions of these journeys with a wide reading audience [98].

Soviet explorations in Mongolia gave rise to many other works about the natural history and geography of this unique country. These include reports on geological explorations; articles on specific problems of geology, geomorphology and paleogeography; summary works on hydrology and hydrogeology, survey monographs and brief summaries on soils, vegetation and natural history in general.

In the same years that the Mongolian Agricultural Expedition and the Paleontologic Expeditions of the USSR Academy of Sciences were working in Mongolia, Soviet geographers, geodesists, cartographers, geologists and other specialists were also exploring certain areas of central Asia located in Western China (the Sinkiang-Uigur autonomous region)*. In 1956, a Joint Soviet-Chinese high altitude expedition worked in the Kashgar Range, the eastern and highest sector of the Pamirs. The expedition studied the glaciers in that region and ascended to the top of Kongurtube-Tag (7,595 m) and Muztagata (7,546 m).

From 1956 through 1960, a large Chinese expedition (the Sinkiang Comprehensive Expedition of the Academy of Sciences of the People's Republic of China) worked in Sinkiang-Uigur autonomous region of China. Taking part in this expedition at the invitation of the Academy of Sciences of the PRC was a large group of Soviet scientists, among whom were those who had recently worked in Mongolia (E. M. Murzayev, N. T. Kuznetsov and A. A. Yunatov).

The expedition's programme included the study of the natural conditions of the vast Sinkiang region, which occupies about one-sixth of the entire territory of China. It studied the southern, Chinese, slope of the Mongolian Altai, the frontier mountains of Dzungaria, the Dzungarian depression

* N. I. Vavilov had visited this region earlier, in 1929, for agronomical purposes.

(not completely), the Southern (Chinese) Tien Shan, the Tarim depression and, partially, the Kunlun Mountains. Murzayev, who headed the Soviet party, was in charge of the physiographical study of Sinkiang. He outlined its physiographic zones, published a series of works on various problems of geography and paleogeography (some of them jointly with N. T. Kuznetsov), and wrote a monograph giving a general description of Sinkiang terrain in connection with the origins of deserts in central Asia. Here, again, he shared his travel impressions with a wide circle of readers [99].

The geomorphological team was headed by B. A. Fedorovich. Making use of new topographical materials and aerial photographs, he drew up a geomorphological map of Sinkiang and a map of its geomorphological zones. He paid particular attention to the characteristics of relief formation in the high mountain area and in the extreme desert regions of southern Sinkiang.

Kuznetsov, who had begun his study of central Asia during the explorations in Mongolia, studied the surface waters of Sinkiang: Bagrash, Airen Kul and other lakes, and rivers, especially in southern Sinkiang and on the northern slope of Eastern Tien Shan. Subsequently he published a number of works on the rivers and lakes (including those that existed in past geological eras) of Sinkiang and all of central Asia, and in a small popular science book [100] he painted a vivid picture of the region and the dynamic, ever-changing hydrography of central Asia.

The expedition also conducted hydrogeological explorations (headed by V. N. Kunin) in the plains at the foot of the northern and southern slopes of Eastern Tien Shan and the northern slope of the Kunlun Mountains.

Soil scientists made soil maps of the mountains and plains of Sinkiang. They paid particular attention to soil reclamation studies and reclamation hydrogeology.

In addition to various articles written by individual members of the expedition, two books, *The Natural Conditions of Sinkiang* and *Kunlun and Tarim*, were published, in which the basic results of the expedition's work were summarised [101].

The deserts of Sinkiang lie within the vast region of Asian deserts stretching from the Caspian Sea in the west to the Hwang Ho River and the Greater Khingan Mountains in the east. They have many features in common with Soviet Cen-

tral Asian deserts, but occupy a central position among the deserts of intracontinental Eurasia and are distinctive for their typically desert landscapes. One of the reasons for this is that they are bounded on all sides by high mountains which form a barrier against the influence of moisture-carrying air currents.

The extremely dry climate in Sinkiang, especially in the Tarim depression in the south, accounts for the fact that even the slopes of the Kunlun Mountains are completely lifeless deserts to the very snow line, which, in turn, is very high.

The climatic influences of the Atlantic seas are felt less here than in the deserts of the Soviet Central Asian republics while the effects of the Mediterranean on organic life diminishes and completely disappears in the central and eastern parts of Sinkiang. High water in the spring is less of a feature here than in Soviet Central Asia because the snow line and glaciers are so high. Murzayev wrote that "even June temperatures are not high enough to melt the ice in the extremely high Kunlun Mountains, despite their location in the southern latitudes".

Many of the natural features of Sinkiang are connected not only with the intracontinental location, orographic isolation and the driest climate in Asia, but also with the geomorphological history of the region. Soviet scientists have determined that the loess-like soil covering the slopes of the Kunlun and Tien Shan mountains came from eolian deposits which originally fell on ancient glaciers and then, as the glaciers melted, descended and packed the slopes. Another complex of loess-like sediment deposited by streams of water occurred in the alluvial fans and in the valleys and deltas at the bottom of the mountains.

The accumulation of sediment in valleys and depressions caused migration of rivers over the level plains, the emergence of large deltas and the shifting of terminal water reservoirs, or lakes without outlets.

Geographers identified two natural subzones in the desert area of Sinkiang—the Dzungarian and the Tarimian. They also ascertained the various elevation related changes in nature that were typical of each of Sinkiang's mountain systems and, on the basis of their study of the vast territory and its natural resources, outlined the prospects for its economic development.

M. P. Petrov, who in 1957-1959 acted as consultant in the programme for studying the deserts and semi-deserts of China, traversed a total of 40,000 km throughout central Asia, 30,000 km of which were in the deserts. The objective of the studies was to work out plans for the afforestation and anchoring of the drifting sands and for the agricultural development of those areas where this was feasible. In 1957, he worked in the Central Hwang Ho Anti-Erosion Expedition (to be discussed), studying sand dispersal in the Ordos and Ala Shan desert regions. In 1958, he was advisor to a special sand study detachment of the Tsing Hai-Gansui expedition of the Academy of Sciences of the People's Republic of China, which examined the sands of the eastern and southern parts of the Ala Shan desert. The following year, this detachment was expanded to form a comprehensive sand study expedition, which set up a number of experimental stations for this purpose. Petrov worked in the methodological detachment, with which he travelled over a vast territory in the western part of central Asia, including the deserts in southern Dzungaria, the Tarim basin (the Takla Makan desert) and the deserts of the Tsaidam Depression, which lies at an absolute elevation of 3,000 m.

"Now, looking at a map of central Asia," wrote Petrov, "I see the picture of its deserts in all its diversity.... I see in my mind's eye the disorderly accumulation of low ridges and rocky hills, the motionless waves on the boundless seas of sand, the burning deserts of rock and pebbles; the white solonchaki sparkling in the sunlight, and the flat blue-green bowls of the salt lakes. The wide dark-green ribbons of the river valleys cutting across the desert are in sharp contrast to the sun-scorched red and dirty-yellow desert plains that are almost devoid of vegetation" [102].

The explorer heard the "singing" of the sands and observed dust hurricanes. He described the work of the expedition and its results in a number of publications, including a major work, *The Deserts of Central Asia*, which contains a comprehensive description of Ordos, Ala Shan, Bei Shan, Tsaidam, and the Tarim basin [103].

The landscape in central Asia is unusual and, at the same time, full of contrasts. "If you ask someone who has visited even some one small part of central Asia what he remembers about it most of all, he is most likely to say — the contrasts," writes N. T. Kuznetsov. "They are everywhere and ev-

erything. There are, for example, the majestic and austere six and seven thousand metre-high Kunlun and Tien Shan mountains, proud of their inaccessibility, glaciers and snow caps. Yet, right next to Bogdoshan (5,445 m above sea level), one of the highest ridges in the Tien Shan, is the deep Turfan Depression, whose bottom lies 154 m below sea level. In the summer, it is full of incinerating desert heat, which penetrates even to the oases.... There is plenty of heat and light in the depression. But if you leave the depression and climb the nearest mountain (in the same latitude), it is like going from the tropics to the Arctic."

"You can go hundreds of kilometres in central Asia without coming across any lakes, streams, or even puddles — only wells, often with salty and musty water. Yet the mountains in the north and west abound in crystal clear streams and rivers" [104].

In the Kunlun Mountains one can see exudations and incrustations of salt, characteristic of deserts, existing right near perennial snow and glaciers.

The relief of the sandy desert land is varied. The almost flat plain in the southwestern part of the Takla Makan desert contrasts with the ridgy sands in other parts. In the Kumtag sand massif adjacent to the Takla Makan desert, the ridgy sands, which run in the direction of prevailing winds, reach 450 to 480 m in height — higher than in any other desert in the world!

Many of the geographical discoveries in central Asia which resulted in substantial changes in its geographical map were connected with the wandering rivers and shifting lakes in its plains. One of the distinctive features of central Asia is its "roaming" landscapes, both natural and cultivated. The frequent shifting of river beds and of the subterranean streams under them, which were formed by seepage, made irrigation farming difficult and required constantly moving oases to new locations. The same thing happened with the natural landscape. "The *tugai** forests and the vegetation of the hummocky sands migrate along with the surface and subsoil water: along the beds abandoned by a river the *tugais* dry out and become covered with sand, while along the banks of the new river bed a young forest would rapidly emerge" [105].

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* The name *tugai* refers to the thickets of brushwood growing in the river floodlands.

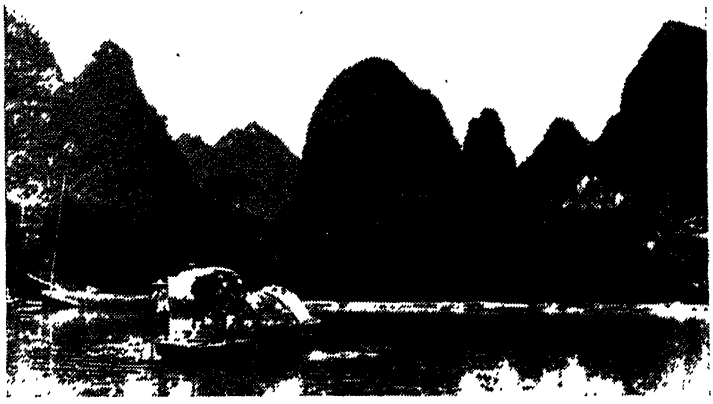
Soviet researchers have unravelled many amazing riddles concerning the present and distant past of central Asia. They have studied not only the sands of the hot deserts, but also the glaciers in the high, cold mountain chains—the Kashgar Mountains (1956), the Eastern Tien Shan and the Nan Shan (1958, 1959), down which rivers flow to give life to the desert oases. Soviet glaciologists took part in making the first estimate of the area of glaciation and of the glacial water reserve of the Eastern Tien Shan and the Nan Shan. The morphological features, regime, dynamics and evolution of the glaciers have been determined, and experiments in the artificial intensification of glacial melting have been carried out. The pattern in which glaciers are arranged has been established, traces of ancient glaciation have been studied, and a special central Asian continental glacial province has been singled out.

Besides the surveys mentioned above in the discussion of the individual expeditions, Soviet researchers have written many other surveys on central Asia, its geological structure and paleogeography (special mention should be made of the works of V. M. Sinitsyn and E. I. Selivanov), the desert salt lakes, etc.

The Geographical Society of the USSR awarded the Przhevalsky Gold Medal to E. M. Murzayev, V. M. Sinitsyn and A. A. Yunatov for their outstanding work in the study of the geographical and other natural features of central Asia. M. P. Petrov was awarded the Society's Grand Gold Medal for his work, *The Deserts of Central Asia.*

In 1957-1958, a team of Soviet scientists, headed by D. L. Armand, worked with the Central Hwang Ho Anti-Erosion Expedition of the Academy of Sciences of the PRC in an area adjacent to the southeastern outskirts of central Asia.

Exploration was conducted in the great bend of the Hwang Ho River within the bounds of the Loess Plateau (in Shensi province, the western part of Shansi, and the eastern part of Kansu), and some trips were also made into the Ordos. Members of the team also went into the Tsinling Mountains. The main objective was to determine what measures could be taken to combat erosion in the Hwang Ho River basin. The silting up of the reservoirs near the Sanmenhsia dam on the Hwang Ho had to be prevented, and conditions for agriculture in the Loess province, as the explorers called the



Karst landscape in southern China

Loess Plateau, had to be improved. The implementation of a series of anti-erosion measures on the fields of the Loess province made it possible effectively to combat soil erosion and maximally reduce drainage into the valleys of the Hwang Ho River system. The composition and structure of the loess layer and loess relief, the soil and vegetation, and water drainage and filtration were studied. Recommendations were made for the reorganisation of the agricultural area in line with the anti-erosion measures.

Soviet explorers have also worked in Eastern China, the eastern part of Tibet and the southern provinces, everywhere conducting geological, geomorphological, paleogeographic, ground cover and soil studies. In a number of regions (the island of Hainan, Kuantung, the North China Plateau, the Yanshan Mountains and the Taihang Shan in northern China) the explorations were led (1957-1958) by A. G. Isachenko, a physiographer and expert on landscapes. He drew up a general map of the landscapes of China, published a series of fragments of landscape maps, and worked out the physiographic zoning of separate regions. Biogeographer A. G. Voronov studied the subtropical forests in Yunan province in southern China (1958-1959).

N. I. Vavilov in Africa (April 1927)

The studies made by Soviet geographers and geologists of the remnant tropical karst land forms in the southern provinces of China were of great scientific interest. This refers to limestone rocks in the shape of high cones or towers which resulted from a long erosional process in the warm and humid tropical climate. Soviet geographers studied similar karst land forms in North Vietnam. V. M. Friedland, for example, made a study of the soil and mantle of waste in the humid tropics of North Vietnam. He wrote a book on the physical geography of the country and drew up a diagram of its geographical zones [106]. Soviet scientists have also been to Burma, India, Pakistan, the Korean People's Democratic Republic, Japan and Ceylon.

In 1925 botanist E. G. Chernyakovskaya visited Iran and subsequently published an article on Seistan, a land located on the outskirts of the huge Lut desert on the eastern frontiers of Iran [107]. This is an oasis where the summers are incredibly hot. Even in October, when Chernyakovskaya was there, the temperature does not drop below 40-45°C in the daytime. Chernyakovskaya singled out five geographical regions in Seistan. In her article, she described the natural and cultivated vegetation of the area and provided ethnographical data on the Baluchi (people from Baluchistan).

The All-Union Institute of Plant Growing organised a number of expeditions to western Asia. The work there was headed by Academician N.I. Vavilov, who took a direct part in some of the expeditions. Following the expeditions, monographs on individual countries appeared, which contained, besides valuable material specifically on plant growing, abundant information of a general geographic nature. The

A savanna landscape in Niger

Russian Geographical Society awarded Vavilov the Przhevalsky Gold Medal for his research in Afghanistan (1924).

Soviet geographers have visited many European countries, and conducted scientific observations there.

In Bulgaria, Soviet and Bulgarian geographers conducted joint expeditionary explorations. Soviet geographers published a number of works on the relief, soil and other aspects of Bulgaria's physical geography. They also took part in a project undertaken by the Rumanian Academy of Sciences to produce a two-volume *Geography of Rumania*, for which purpose joint expeditions were likewise conducted (1955-1957). Among the other countries visited by Soviet geographers are Poland, Yugoslavia, Finland, Sweden, Norway and Iceland, where they explored and made observations on the relief, studying in particular the coastal, karst and glacial land formations, soil conditions, etc.

Africa is another area that has drawn the attention of many Soviet naturalists and geographers. In pre-revolutionary times, a number of Russian travellers had visited and ex-

plored Ethiopia (Abyssinia). Soviet scientists continued this study. A big expedition to Ethiopia was outfitted in 1926-1927 by the All-Union Institute of Plant Growing, under N. I. Vavilov. In the course of four months the expedition's caravan covered a distance of 2,000 km within Ethiopia, collected over 6,000 samples of cultivated plants and many soil samples, and took about 2,000 photographs. The results of the work were published in a series of special works on the cultured plants of Ethiopia.

The expedition's detailed study of Ethiopia's plant resources and farming gave science new information on the origins and history of many important cultured plants. Vavilov established the fact that hard varieties of wheat originated in Ethiopia [108].

In 1948, L. G. Voronin, on the staff of the Sukhumi Primate Research Centre, went to Ethiopia. He described the physical features of the country, its capital, Addis Ababa and told the story of his adventures while hunting monkeys in various parts of Ethiopia.

Soviet scientists taking part in various international scientific congresses have visited other parts of Africa. These included N. M. Fedorovsky, with the 15th Geologic Congress in 1929; I. P. Gerasimov, G. V. Bogomolov, K. A. Vlasov, L. V. Pustovalov and M. B. Gornung, with the 19th Geologic Congress in 1952; and P.A. Baranov, A.L. Kursanov and others, with the 8th Botanical Congress in 1954. They published their impressions giving valuable descriptions and special scientific information on the natural history and geography of the countries visited, which were primarily in northern and western tropical Africa [109]. I. P. Gerasimov made a second visit to Africa to make a study of Guinea. Geographers who have visited African countries as members of specialised tourist groups have also in some instances made certain scientific observations or were able to share their travel impression with their readers.

Recently (1967-1969) a Comprehensive East African Expedition, outfitted by the USSR Academy of Sciences, worked in Africa (headed by A. P. Kapitsa, with V. V. Belousov as chief scientist). The expedition's work was basically of a geological and geophysical character and was conducted in accordance with an international programme for the study of the Earth's mantle. The Soviet expedition was invited to work in Kenya and Tanzania to study the prob-

Western Africa. At the lower reaches of the Volta River

lems connected with this project, the specific objective was to investigate the system of the Great Rift Valley. Besides the varied geological and geophysical explorations it conducted, the expedition made geomorphological observations, studied the mantle of waste, etc.

Soviet scientists have made fruitful trips to countries in the New World. In 1925, Moscow University professor of geography B. F. Dobrynin made a trip to Mexico and later published a geographical sketch of the country based on his personal impressions [110]. In 1956, a group of Soviet geologists, attending an International Geologic Congress in Mexico, took part in a scientific expedition through the country. And Soviet geographers have also travelled within the United States, in 1961 and 1965 in particular (in connection with a congress of the International Association for the Study of the Quaternary Period). Original scientific material was gathered in some instances during these trips.

Geographers from the Institute of Geography of the USSR Academy of Sciences and other Soviet scientists worked with their Cuban colleagues in compiling a geographic atlas of Cuba [111].

Soviet naturalists and geographers have also made frequent visits to South America. In 1926, a Soviet expedition headed by Y. N. Voronov worked in wilds of the Amazon forests (in Amazonian Colombia), in the Central Cordilleras and in Venezuela. It was sent there by the Rubber Trust and Chemical Administration of the Supreme Economic Council to study rubber-bearing plants, the local climatic conditions and to gather as complete as possible a collection of rubber-bearing trees and to bring their seeds to the USSR. A man from the All-Union Institute of Applied Botany and New Crops was sent along with the expedition to gather seeds of local cultivated plants. In Colombia and Venezuela, besides travelling through the forest wilds, the expedition went through desert areas, savannas and typical llanos. Besides fulfilling its assignment and conducting general botanical-geographical investigations, the expedition had an opportunity to gather some valuable ethnographic material for the Academy of Sciences' Museum of Ethnography. This gave the museum some exhibits that even the best European museums and collections (Paris, Berlin) lacked. Y. N. Voronov wrote an interesting article on his travels in Colombia [112].

S. V. Yuzepchuk, a member of Voronov's expedition, continued the exploration of South America. In 1927-1928, he was in Peru, Bolivia and Chile, doing work for the All-Union Institute of Applied Botany and New Plants. He traversed the main geographical zones of Peru, the puna region in Bolivia and the southern region of Chile. Yuzepchuk devoted special attention to the many varieties of potatoes he found there. All in all, he collected about 5,000 herbal specimens and 2,500 specimens of cultivated plants, and took over 600 photographs.

N. I. Vavilov travelled extensively in South America in 1930 and 1932-1933, visiting Ecuador, Peru, Chile, Bolivia, Brazil and Argentina studying agronomical history in those countries. In his interesting travel notes and reports he also described the then current situation in plant growing and the use of vegetation resources in the countries he visited [113].

In 1947, a team of botanists was attached to a Soviet solar eclipse expedition to Brazil, and in 1956 delegates to the 18th International Geographic Congress also visited various regions of Brazil. L. E. Rodin, of the team of botanists, and geographers I. P. Gerasimov and S. V. Kalesnik published books and articles about their travels [114].

While Soviet researchers played a leading role in the study of the natural and geographical characteristics of many foreign Asian countries and their work there was accompanied by important scientific discoveries, the same cannot, of course, be said about Soviet explorations in Europe (outside the USSR), Africa and America. However, in the latter parts of the world, Soviet scientists have carried out many original scientific observations, gathered important material and made a substantial contribution to the study of geography.

CHAPTER 12

THE FIRST SOVIET EXPEDITION TO ANTARCTICA. WORK DURING THE INTERNATIONAL GEOPHYSICAL YEAR

The explorations of the south polar lands taking place in our time constitute one of the most intriguing pages in the history of the scientific conquest of the Earth.

D. I. Shcherbakov

In the southernmost latitudes, where in the first quarter of the 19th century a Russian expedition under F. F. Bellingshausen and M. P. Lazarev—the First Russian Antarctic Expedition, as it came to be called—discovered the sixth continent, Soviet scientists and specialists have carried out a broad programme of explorations and have made a number of outstanding discoveries. Explorations continue to this day.

Soviet explorations in Antarctica began with scientific observations by the Antarctic Whaling Flotilla *Slava*, carried out yearly for many years beginning with the 1946-1947 fishing season.

The scientific work was under the auspices of the All-Union Scientific Research Institute of Fishing and Oceanography. Personnel from the State Institute of Oceanography were also attached to the flotilla's team of scientists.

Besides the special studies directly connected with whaling (organisation of the industry, whale biology, the technology of processing and utilising the various kinds of whale raw material), the scientists made a general study of Antarctica, its fauna, climate, ocean water, ocean currents and ice conditions.

Weather observations consisted of measuring temperature and humidity, wind velocity and direction, etc. On the basis

of these observations, the State Institute of Oceanography published several books on antarctic weather conditions.

Extensive oceanographic research was carried out. Records were kept of the temperature, salinity, oxygen content, transparency and colour of the water. Temporal changes in temperature, salinity and oxygen content were measured at various depths up to 300 m (measurements at three-hour intervals). Deep water hydrological studies were also made, in which cores were taken for laboratory analysis and the water temperature measured to depths of up to 3,000 m.

A much more extensive research programme, embracing not only the ocean waters of Antarctica but the continent itself, was launched in 1956, in connection with the International Geophysical Year (IGY), which began July 1, 1957.*

In preparing for this great scientific undertaking, the international IGY committee** reviewed the general plans for the upcoming investigations and urged that as many countries as possible organise geophysical observations in Antarctica, since that remote and inaccessible region remained the least studied part of our planet. Soviet scientists and the Soviet government did not hesitate in responding to this call: in July 1955, the government of the USSR announced its decision to send a large expedition to Antarctica. Direction of the scientific work was assigned to the Academy of Sciences of the USSR, while the preparations and technical outfitting came under the Chief Northern Sea Route Administration, which had a great deal of experience in the exploration of the Arctic.

The USSR Academy of Sciences set up a special Council on Antarctic Explorations***, headed by Academician D. I. Shcherbakov, to carry out the scientific direction of the expedition. The council worked in close contact with the Chief Northern Sea Route Administration, which, with the co-operation of many scientific institutions and departments (the Chief Hydrometeorological Services Administration, the Ministry of Fishing and others) was organising and equipping the expedition.

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* The *Slava* whaling flotilla also continued working in the antarctic waters after 1956.

** See footnote on page 55.

*** Now called the Interdepartmental Commission for the Study of Antarctica.

The expedition's programme included work along many lines: studying the influence of antarctic atmospheric processes on the overall circulation of the Earth's atmosphere; studying the basic movement patterns of antarctic waters and their connection with the overall water circulation of the World Ocean; studying the geological structure and history of the ocean floor in the antarctic region; studying the ice conditions of the antarctic waters; studying the waves in the south polar basin; studying the raw material basis of antarctic whaling; studying the zonal distribution of the fauna in the World Ocean; physiogeographic mapping and description of Antarctica; studying the glaciers of Antarctica and their dynamics; compiling a geological description and studying the geological history of the antarctic region; studying the peculiarities of the geophysical phenomena in Antarctica (the geomagnetic field, earth currents, conditions of the ionosphere and polar aurora, cosmic rays, seismic waves); studying the biogeographical characteristics of Antarctica; developing methods of aeronavigation in Antarctica; and drawing up the navigational and hydrographic characteristics of the regions through which the expedition sailed.

The IGY was planned as a period, to run from July 1, 1957 to December 31, 1958, during which a wide scope of scientific observations would be conducted according to a single plan that had been worked out and co-ordinated at a series of international conferences. However, the complexity of organising and conducting research in severe antarctic conditions required that work on establishing a scientific base on the continent be started ahead of time.

The plan was to set up three basic scientific stations on the continent and to conduct studies of the ocean and coastal waters from a specially equipped ship. One station, which would serve as the expedition's main base and observatory, was to be set up in a coastal strip facing the Indian Ocean that was virtually unexplored and was shown with a dotted line on the map. The other two stations had to be set up far inland, one in the region of the south geomagnetic pole, and the other in the region of the Pole of Inaccessibility (or, more precisely, the Pole of Relative Inaccessibility), that is, at a point far removed from the sea coasts and where man had never set foot before. The two remote points were to be reached from the main base.

The main task of the 1955-1957 Soviet Antarctic Expedition—or the First Soviet Antarctic Expedition, as it came to be called—was to build the main base and a geophysical observatory. In addition to this, it was to make several geographical examinations of the regions in which work was to be conducted, organise a short programme of stationary observations at the coastal observatory, and conduct oceanographic work in the antarctic waters.

M. M. Somov

The expedition was given three ships: the *Ob* and the *Lena*, diesel-electric ships, each with a displacement of 12,600 tons and a carrying capacity of 4,500 tons, and the *Refrigerator No. 7*, with a 2,200 tons displacement, designed to carry perishables.

The First Soviet Antarctic Expedition was placed under the command of M. M. Somov, a noted polar explorer who had headed the North Pole 2 scientific drifting station in 1950-1951. The expedition's personnel included scientists in varied fields, the ships' crew airplane pilots, technicians and building workers. All in all, about 350 men took part.

The expedition was broken down into two big sections or groups—a land group and an ocean group — each an independent expedition to a certain extent. The land section was made up of four units: aerometeorological, geophysical, geographical-geological and air photography. The ocean section had seven units: hydrological, hydrographical, marine geological, hydrochemical, hydrobiological, geophysical and aerometeorological. These units comprised the First Antarctic Marine Expedition, headed by oceanologist V. G. Kort, who was at that time director of the Institute of Oceanology of the USSR Academy of Sciences. The marine expedition was later given the diesel-electric ship, the *Ob*, which had

been especially outfitted to conduct oceanographic studies and became the largest research ship of its type.

The *Ob* set out for Antarctica from Kaliningrad on November 30, 1955. On board was the first group of participants in the Soviet Antarctic Expedition, namely, the leadership of the expedition, a large part of its scientific personnel and the building crew that was to build the future settlement of the coastal base. Two weeks later, the remaining members of the expedition departed for Antarctica aboard the *Lena*.

In early January 1956, the *Ob* approached the shores of Antarctica and entered Depot Bay (Davis Sea) in the region of Queen Mary Land. After lengthy air reconnaissance, a piece of ice free land was spotted west of Depot Bay and south of Haswell Island, along a strip of coastline called Pravda Coast. On January 14, the *Ob* came up as far as the fast ice at the contemplated disembarkation point and stopped 100 m from shore. Unloading was a very complicated procedure.

The *Lena* arrived at Pravda Coast on January 20, and the *Refrigerator No. 7*, on February 8, 1956.

Scientific reconnoitring and construction of the coastal base settlement began immediately. Houses for living quarters, scientific studios, receiving and transmitting radio stations, an electric power station and other structures were assembled out of prefabricated panels. The construction crew, with the help of the entire expedition staff, completed construction of the settlement in the course of the antarctic summer of 1955-1956.

The ceremonies marking the opening of the observatory and settlement took place on February 13. On that bright, sunny day, the red flag was hoisted at 66°33′S and 93°E. The observatory and settlement were officially called Mirny, in honour of one of the ships of the First Russian Antarctic Expedition under F. F. Bellingshausen and M. P. Lazarev.

From that day on, regular aerometeorological, geophysical and glacial observations were conducted, and as time went on, the scope of research, especially the geophysical work, was broadened.

Most of the houses and other buildings were built along one main street, which was called Lenin Street. Nearer to the sea, some small buildings were erected here and there on the rocks along the shore.

Once the village was built, the *Lena* took the construction crew back home to the Soviet Union, the *Refrigerator*

The First Soviet Antarctic Expedition. Unloading the *Lena*

No. 7 headed out to sea where the *Slava* whaling flotilla was working, and the *Ob* marine expedition began to carry out its research programme in the antarctic waters. About 90 men remained to spend the winter on the mainland.

Members of the expedition began their scientific investigations immediately, that is, not only before the building of Mirny was completed, but from the moment the ships were being unloaded. At first they studied the coast in the disembarkation region, as well as Haswell Island and its neighbouring small islands. It turned out that the coast and the islands were ten miles further north than shown on the maps of the British Admiralty.

At the end of January, when the unloading of the ships was in full swing, scientists and flyers explored the Bunger Oasis, located 360 km east of Mirny. It was so named after D. E. Bunger, an American flyer under whose command an airplane of an American antarctic expedition made a flight over the antarctic coast in 1947. It was then that flyers first saw along the edge of the Shackleton Glacier "a land of blue and green lakes and brown hills".

A 13-man team, flown in two airplanes and a helicopter, flew to the oasis, spent six days studying that unique place where an area of about 500 sq km was devoid of ice cover. Among the first Soviet scientists to visit the oasis were geographers G. A. Avsyuk, K. K. Markov and P. A. Shumsky and geologist O. S. Vyalov. A temporary base was set up on the nearby glacier, and from this take-off and landing strip, the helicopter took the explorers to the centre of the oasis.

The surface of the oasis is rocky, with numerous hills, with moraine-filled depressions between them. The hollows abound in lakes. Some are wide and deep fresh-water lakes with drainage, giving off a blue colour, and there are many small undrained salt-water lakes in which the salt accumulation is connected with chemical changes in the rocks caused by atmospheric agents and solar heat.

On sunny days, the temperature of the air at the oasis was about 1° to 3°C while the surface of the dark-coloured, light-absorbing rocks got as hot as 25° to 30°C. The air temperature in the oasis at times rose as high as 7°C, while on the glacier nearby it was —5°C. The oasis had its own microclimate, with summer temperatures considerably higher than in the ice regions surrounding it.

Markov noted that the landscape of this antarctic oasis resembled the cold deserts of the Eastern Pamirs. It has also been compared with the cold deserts of the high Tien Shan watershed regions (*syrts*), however, it is more desolate and incomparably more lifeless. It is a really cold rocky desert where the air is exceptionally dry, the relative humidity averaging only 50 per cent. The word "oasis" is applied to such localities in Antarctica in a highly conditional and relative sense; it is a lifeless desert oasis in the midst of an even more lifeless and colder desert of ice.

The oasis is more dreary and silent than the rocky area around the Mirny settlement where there are penguins to liven up the scene. But one can see snow petrels and skuas in the clefts of the rocks. The rocks are covered with lichen and mosses.

While Bunger Oasis is but one of many oases in the coastal zones of Antarctica, it is one of the largest.*

The expedition soon began making air reconnaissance flights to the interior regions of the continent. Taking advantage of the clear weather, flyer I. I. Cherevichny took expedition commander Somov and other members of the expedition on a flight in an IL-14 aircraft over the geomagnetic pole and the region where the Vostok station was to be set up. It was determined during this and subsequent flights that the area between the Mirny observatory and the future Vostok station was a high and relatively level ice plateau.

On a clear day in the beginning of March, the same party flew in the direction of the Pole of Relative Inaccessibility as far as 76°S and 79°E. The nature of the ice sheet there was the same; there was no sign of the mountain chains that were shown on some American maps as lying between Mirny and where the future station, Sovetskaya, was to be set up 300 km from the coast.

A few days later, a light AN-2 ski-plane flew a distance of 400 km from Mirny and landed on the ice sheet at an elevation of 3,000 m. Upon landing, the party, headed by A. M. Gusev (or more exactly, Gusev and the flyers), set up a semi-spherical tent of the same kind that was used in the North Pole drifting stations in the Arctic. With the help of the flyers, Gusev conducted continuous observations for

* Another large oasis is the South Victoria Land Oasis.

Landing strip at Mirny

a period of five days. They found a remarkably big difference between the temperature of the air there on the ice sheet and the temperature prevailing at Mirny. At Mirny, the temperature was —5°C, while at the landing point it was —45° to —50°C. The cold, the constant ground wind and the rarified air made living and working there extremely difficult. The men got an idea of the conditions that the workers of the future interior stations would have to cope with.

In the beginning of April 1956, a tractor-and-sledge train carrying a party headed by Somov left Mirny for the deep interior of the continent. A. M. Gusev, a member of that party, wrote: "I will long remember the picture: it was night. The wind was roaring over the icy desert, blowing up a solid wall of snow. The vague contours of the tractor and the heavy sledges could barely be seen through the whirlwinds of snow. Two dim spots of light from the headlamps moved through the dark of night. You could hear the

laboured roar of the motors, and in front of the tractor in the weak beam of the headlights you could see two human figures holding ice picks; they were bending forward against the wind and doggedly stepping into the unknown" [115].

The train perforce moved very slowly. First it ran into a steep upgrade and loose snow, then high rugged sastrugi and a blizzard. When the train stopped for a day or two, the tractor and sledge got covered with snow, which the men had to clear away before they could move on.

Despite the harsh conditions, the members of the party conducted scientific studies of the region during the short stopovers. They systematically took meteorological observations, measured the Earth's magnetism and studied the snow cover. At a number of points, using seismic methods, they measured the thickness of the ice. It was over two kilometres thick, and in places the underlying rock lay below sea level.

According to the original plan, the train was supposed to travel a distance of 400 km; however, at the half-way point, it was already clear that there would not be enough fuel to make it that far and back to Mirny. So it was decided not to return but to go south for as far as possible and convert the train into an interior scientific station.

Twenty days after the trip began, when the train had traversed 215 km, two airplanes arrived from Mirny. Somov returned to Mirny on one of them, and Gusev took charge of the party for the remaining distance.

The train proceeded southward slowly. It was now May, already a winter month, and the temperature dropped to between —50° and —60°C. The days were getting shorter as the polar night approached.

By May 4, the train had reached a point 375 km from Mirny, and it was decided to set up the station right there. That day, an AN-2 aircraft delivered provisions, building materials, and a carpenter. It took till the end of May to build the station and set up its equipment. The official opening took place on May 27, 1956. This, the first station in the interior of Antarctica, was named Pionerskaya.

A meteorological platform and a snow-measuring platform were set up at the station; a 16-metre long hole was bored in the ice to study the upper layer of the continent's coat of ice; and instruments were set up for various kinds of observations.

After May 25, the sun no longer rose above the horizon. The polar night had begun and would last till July 20. The darkness and continual bad weather made flights with supplies for the station nigh on impossible. The last plane to make it through (June 7) brought a radio-operator and a glaciologist and took back to Mirny part of the tractor-sledge train party. Remaining at the station for the winter were A. M. Gusev who was in charge of the station and was himself a meteorologist; geographer and glaciologist L. D. Dolgushin; a radio-technician and a tractor driver. The winter party was cut off from the outside world for almost six months; the only communication with it was by radio.

The members of the winter party underwent many harsh ordeals during the polar night. Gusev registered a temperature below —66.7°C on August 20. There were strong winds and snow-storms and the men could feel the oxygen deficiency in the rarified atmosphere at the high absolute elevation.

On November 17, 1956, a new party was flown from Mirny to relieve Gusev's group. The latter in turn was flown back to Mirny on the same plane.

Living conditions had changed considerably in the winter. A strong wind from the interior to the coast blew almost incessantly from the beginning of April on. The houses and other structures were soon buried in snow. The only way to get out was through holes in the roofs.

To study the drainage winds blowing from the interior of the ice-covered continent, four temporary observation stations were set up in the coastal zone. The observers had to live there in tents in the worst weather (August).

In September 1956, that is, at the end of winter, the party based in Mirny started in on the job of setting up a small permanent station in the centre of the Bunger Oasis. Tents, building materials, a small tractor, a radio station, scientific equipment, fuel (gas) and provisions were flown to the oasis. Two light-weight prefabricated houses were rapidly assembled, and rocks were piled almost half way up the side exposed to the wind. Oasis, the third Soviet station in Antarctica, was ready for operations on October 15, 1956.

In the summer season of 1956-1957, the geological and geographical unit of the First Soviet Antarctic Expedition made an extensive exploration of the coastal zone. The

glaciologists in this unit made several flights to the islands, the Shackleton Ice Shelf and floating icebergs. Wherever they landed they conducted glaciological, gravimetrical and seismic sounding observations.

The First Antarctic Marine Expedition began its independent work on the last day of February and continued until July 1956.

On February 29, the *Ob* set out from Pravda Coast on an oceanographic voyage. It carried a total of 115 men—48 scientific workers and 67 members of the ship's crew.

The expedition made an oceanographic survey of the Davis Sea and conducted interesting observations of its organic life. The ship sailed through waters where the depths were virtually unknown. After the expedition returned home, a new sea navigation chart of the Davis Sea was drawn up and published. This expedition discovered and probed an underwater trench with depths of up to 1,440 m stretching parallel to the coastline. Subsequent Soviet oceanographic explorations traced the trench for a long distance along the antarctic coast and found that in some places it passed under the ice shelves. Later, this trench, lying within the antarctic continental shelf, was named after M. P. Lazarev.

Sailing among the ice floes and icebergs was difficult since autumn was approaching (it was March, which in the southern hemisphere corresponds to September in the northern hemisphere); there was dense fog, snow and wind. Nonetheless, the ship made systematic stops to conduct hydrological, geological and biological observations. The water at all levels and the ocean floor itself were studied.

The expedition determined that the Shackleton Ice Shelf was considerably smaller than shown on former maps. Moving east along the antarctic coast, the expedition also discovered several theretofore unknown islands, charted the coastline more precisely and carried out comprehensive oceanographic observations.

Refinements by means of depth soundings were made in the relief map of the ocean bottom, and in some cases the surface contours shown on previous maps had to be changed considerably. For example, when the *Ob* sailed among a huge accumulation of icebergs near the Banzare Coast, it made a depth sounding in a place where the latest maps showed land.

A. F. Treshnikov

On March 27, the *Ob* reached the Balleny Islands, the easternmost point of its first voyage along the antarcti- coast, where it conducted extensive explorations of the wac ters and the ocean floor between 91° and 162°E.

On July 5, the *Ob* arrived in Leningrad, having conducted on the way back another series of studies in the antarctic waters and the Indian Ocean.

In November 1956, the *Ob* sailed once again from Kaliningrad to Antarctica. On board was the first party of the second staff of the Soviet Antarctic Expedition, that is, part of the staff of the Second Expedition which was to relieve the winterers of the First Expedition. The Second Expedition was headed by A. F. Treshnikov, a noted polar explorer who had directed the work on the North Pole 3 drifting station in the Central Arctic.

The basic task of the Second Expedition (1956-1958) was to set up the Vostok and Sovetskaya stations in the interior of the continent and to begin full-scale scientific observations at the already existing and newly set-up stations in accordance with the IGY programme. However, setting up the new stations proved to be such an exceptionally complicated and difficult job that the Second Expedition was not able to carry it out completely.

The *Ob* arrived at Mirny station on December 12, 1956, with the first part of the Second Expedition, which included photographers, geologists, biologists, flyers, radio-operators and a large construction crew. The contemplated aerial photography and geological and biological studies depended greatly on the summer season, which was already at its height in Antarctica. Consequently, no time was wasted in unloading and getting down to work. Even while the *Ob* was still breaking its way through the fast ice, the construction crew was flown ashore by the helicopter so that it would start the job of expanding the Mirny settlement and observatory.

By January 5, 1957, the *Ob* was unloaded and shortly thereafter the motor ship *Kooperatsia* arrived with the rest of the scientific staff of the Second Expedition.

On January 14, the members of the marine expedition, who, together with the ship's crew had taken an active part in the work of unloading the ship and putting up the new buildings in Mirny, set sail on the *Ob* to conduct their oceanographic studies.

The expedition's third ship, the *Lena*, dropped anchor in the Mirny road on January 22. Unloading operations proceeded with exceptionally great complications, and in the beginning of February there was a catastrophe: a huge piece of the ice barrier to which the ship was tied crashed into the sea. Nine men, who were on the barrier receiving the cargo, were plunged into the water along with the great mass of snow and névé. Seven men were saved, but the other two were already dead when they were pulled out of the water.

On February 15, 1957, the *Kooperatsia* and the *Lena* left the Mirny road. The *Kooperatsia* took the members of the previous expedition back home, while the *Lena*, with aerial photography, hydrographic, aviation and hydrometeorological units on board, headed west to

study and take aerial photographs of the antarctic coastline.

The Second Expedition did a considerably wider range of work in aerial photography and establishing astronomical points than its predecessors.

Field work began as soon as the ships tied up at Mirny, even while unloading was still in progress. At the end of December 1956, a party of geologists, headed by Professor M. G. Ravich, arrived at Oasis Station. From there, the explorers flew by helicopter to all the places where bedrock was exposed including the rocky capes on the eastern edge of the oasis. A geological survey in the Bunger Oasis area was made at the end of February 1957.

Forty kilometres south-west of the oasis there is a group of hills which were named the Obruchev Hills, and 15 km north-west of the oasis is another group of hills, named the Maly Oasis. This region was also explored.

In January 1957, geologists were flown 150 km into the interior of the continent to the Amundsen and Sandau mountains, and also 400 km south-west of Mirny to Mount Brown, where they gathered data on Antarctica's ancient crystalline rocks.

After two test trips, a glaciological research train trip was organised to go from Mirny to Pionerskaya to study the thickness of the glaciers and the properties of its snow and névé mantle. The operation was headed by P. A. Shumsky. The data gathered during the trip had to do with the thickness of the ice. The greatest thickness encountered was 2,360 m, while the average was 1,500 to 1,600 m.

Between the coast and a point 200 km inland, the bedrock under the glacier was found to be considerably below sea level in places. Beyond the 200th kilometre, a mountain range, under the ice, with elevations of up to 730 m was probed. Deep valleys cutting through the range sank to sea level and even lower. Thus, Soviet explorers in East Antarctica were the first to definitely establish the fact that the edge of the vast continent has sunk there under the weight of the ice sheet and that the low points of its real relief lie below sea level. If the ice were to melt, the continent would rise, and the distance of the so-called isostatic lift would range between 0.5 to 1 km (an average of 800 m). "East Antarctica is not a group of islands, but a continent that has sunk down under the weight of its glacial cover" [116].

In February, a train consisting of three tractors and six sledges in tandem, left Mirny to set up Komsomolskaya Station in the interior of the continent. This station was not in the original plan, but after it was learned just how difficult work and movement in the interior was and what tremendous difficulties the 1,500 km trip to the south geomagnetic pole would pose, it was decided to set up an intermediate auxiliary station 850 km from Mirny. After passing Pionerskaya, where it had stopped for a week to repair the sledges that were damaged in traversing the rugged country, the train headed further south. Movement was now hampered by the snow cover, which consisted of tiny ice crystals resembling dry sand.

The tractors whirled in place, while the runners on the sledges did not slide easily. The temperature had dropped to —60°C.

On March 7, 1957, the train arrived at the point where Komsomolskaya Station was to be set up (74°05′S, 97°29′E). The temperature at night here was as low as —69°C. The skis on the planes that flew in from Mirny would not slide, making landings and take-offs extremely difficult.

The idea of wintering at Komsomolskaya that season had to be abandoned. It would have required many flights to deliver everything needed for a winter stay, but that was out of the question because hurricane winds were blowing in Mirny and the planes were grounded. There was just enough flying weather left to fly the men who had gone by train back to Mirny. The three tractors and the sledges with cabins on them had to be left till spring.

The reasons for the failure in organising the winter set-up at Komsomolskaya were the late arrival of the ships that brought the Second Expedition to Antarctica, the prolonged and difficult unloading operations, and the consequent late departure from Mirny of the sledge train.

In late February, another train left Mirny, this one even bigger than the one that had gone two weeks earlier to set up Komsomolskaya Station. This one consisted of five tractors and ten sledges. Its objective was to set up Vostok Station at the south geomagnetic pole. However, it reached that point only nine months later, in December. On the way, during a stopover at Pionerskaya, it was decided that the train should stop at some intermediate point where a temporary winter station would be set up. Such a station was

established on March 18, 1957, 640 km from Mirny (at 72°08'S and 96°35'E).

"We dubbed it Vostok-1," writes A. F. Treshnikov. "By so calling it, we wanted to underscore the fact that we had not abandoned the attempt to organise the Vostok Station in the region of the south geomagnetic pole, and that Vostok-1 was but the first step towards this end" [117].

In the meantime, hurricane winds were raging over the coast. On March 21, a hurricane with winds over 40 m per second burst over Oasis Station. The aerological platform, which was built out of thick squared beams and plywood panels, was wrecked and carried away part by part, and the bamboo radio tower was destroyed. There were violent hurricanes in April as well. In Mirny, there were winds of up to 30 m per second, while at Oasis Station they exceeded 50 m per second, breaking the radio tower again and tearing and carrying away a tent.

A furious hurricane hit Mirny in mid-August, with gusts of over 45 m per second and, at its height, of over 50 m per second. People going out-of-doors when the hurricane first started were knocked down and received injuries. Later, it was absolutely impossible to go outside. Boards, pieces of plywood, empty crates and barrels were flying by at a tremendous speed no less than two metres above the surface of the snow. There was much damage in the settlement, while at the airfield two airplanes were torn from their ties and damaged.

The men who went with the trains to the interior and those already manning existing stations were not the only ones whose work was complicated, difficult and dangerous. There was danger lurking even in Mirny and the area immediately around it. For example, there were large clefts in the ice around Mirny that were concealed from view by a layer of snow, so there was always the danger of someone falling through the snow into them. This actually happened to A. F. Treshnikov, the head of the Second Soviet Antarctic Expedition. "He fell into a gap in the ice one day while examining a coastal precipice in search of a suitable place for future unloading of ships. Georgi Matveichuk was standing right next to him when suddenly at the spot where the impressive figure of his chief was standing a moment before there was only a gaping hole about half a metre in diametre.

Treshnikov was hanging by his elbows just above the water that filled the crack. It was sea water, such as penetrates into such cracks near the shore, but for someone falling into it, it was no better than any other kind of water.

"Help came immediately, but when Treshnikov was pulled out of the cleft, it was found that he had dislocated his arm in the fall. Bearing the pain, he had held himself on his injured arm and, thanks to his endurance, saved his own life. Everybody went on the double to the medical unit. On the way, however, Treshnikov slipped, fell—and set his arm back into joint! The doctor had only to apply a compress" [118].

Plane landings and take-offs were also dangerous. In early January 1958, for example, in taking off for a return flight from Mount Brown, an aircraft carrying a party headed by P. A. Shumsky "got one of its skis snagged on the sastrugi, causing the plane to crash. The motors and wings were knocked off. Fortunately, the men were not injured. They say this rarely happens..." [119].

On October 8, 1957, a sledge train with six tractors started out from Mirny into the interior. On October 16, it arrived at Pionerskaya; on October 29, it reached Vostok-1 Station; and on November 4, it came to the place where the Komsomolskaya Station train had been left. On November 6, Komsomolskaya Station began to function. Aerometeorological observations were organised and a landing strip cleared.

Back in March 1957, a minimum thermometer had been mounted on one of the sledges that was left when the men were evacuated. It showed that during the winter the temperature had reached —74.5°C.

Once Komsomolskaya Station was set up and four men left there to operate it, the temporary Vostok-1 Station, which had operated for eight and a half months, was dismantled. All of its equipment was brought to the region of the south geomagnetic pole, where, on December 16, 1957, Vostok Station was officially opened. Located 1,410 km from Mirny, at an elevation of 3,490 m, Vostok became the second (after Mirny) Soviet observatory in Antarctica. It was named in honour of the Bellingshausen-Lazarev expedition's ship, the *Vostok*.

Treshnikov himself took command of the tractor and sledge train that went from Komsomolskaya to the south geomagnet-

ic pole. "The trip into the interior of the continent was difficult and dangerous," he wrote later. "The constant head wind and severe frost, the high and rugged sastrugi, and the rarified atmosphere impeded our movement" [120].

Once the pole was reached and the station set up, eight men stayed with it.

The Second Antarctic Marine Expedition, headed by Professor I. V. Maksimov, began its independent operations on the *Ob* in January 1957. The *Ob* sailed from the Mirny roadstead on January 14, and headed north through Davis Sea, making a meridian traverse along 92°E to 60°S. The expedition's staff consisted of 65 men, not counting the ship's crew.

Besides the work at oceanographic stations along the traverse, the expedition conducted systematic aerometeorological investigations, took soundings with its echo sounder, made observations on the condition of the sea, the animal and bird life and the nature and arrangement of the ice.

Upon reaching the 60th parallel, the *Ob* turned west, and then south again towards Prydz Bay. At the end of January, the ship passed a huge conglomeration of icebergs, numbering several thousands, which sat on a spit stretching north-east from Cape Darnley. From there she sailed west towards Enderby Land. She carried out meridian traverses along 57°, 40° and 20°E. After calling at Cape Town, she set out again for Antarctica, and on April 6, 1957, dropped anchor at the Mirny road.

The *Lena* had also sailed from Mirny, heading west along the coast. At various points shore parties were landed by helicopter for the purpose of taking aerial photographs from AN-2 aircraft. Meanwhile, on board ship, hydrographic investigation went on. At the end of March, the *Lena* headed back for Mirny and arrived at the Mirny road on April 5, 1957, that is almost neck and neck with the *Ob*.

On April 7, both ships left Mirny. The *Ob* sailed north meridionally across the Indian Ocean and arrived in Riga in June 1957. The *Lena* reached Leningrad a month earlier.

The International Geophysical Year began officially on July 1, 1957. The first six-month period of IGY observations on the part of the Soviet Union was conducted by the Second Soviet Antarctic Expedition. By the beginning of IGY, Mirny, Pionerskaya, Oasis and Vostok-1 stations were already operating.

The opening of Komsomolskaya Station in November and Vostok Station in December 1957, marked the final stages of the Second Expedition's activity. On November 18, 1957, just at the time that the tractor and sledge train was at Komsomolskaya getting ready for the trip to the south geomagnetic pole to set up Vostok Station, the *Ob* sailed into the Mirny road with a new research staff.

The Third Continental Antarctic Expedition was under the command of E. I. Tolstikov, who had headed the drifting station North Pole 4 in the Central Arctic.

It was charged with the tasks of setting up the interior Sovetskaya Station, which the Second Expedition was unable to do; reaching the Pole of Relative Inaccessibility; and continuing observations at the already established stations according to the full IGY programme.

Complications developed and an accident took place again as the *Ob* was being unloaded. A sudden storm hit the coast, breaking up the fast ice. As a consequence, some of the cargo ended up on separate ice floes, and it was impossible to save it in the raging storm. An airplane, a tractor and several loaded sledges went to the bottom.

On December 22, 1957, the *Kooperatsia* tied up at the edge of the shore ice near Mirny, bringing the final contingent of personnel for the Third Expedition. In January and February 1958, the ship made two voyages from Antarctica taking the Second Expedition personnel back home.

The main and most complicated stage of the Third Expedition's work was the establishment of Sovetskaya Station and conducting observations at the Pole of Relative Inaccessibility. The leaders of the expedition and its detachments made a reconnaissance flight to that region on an IL-12. The plane circled over the Pole of Inaccessibility, then turned north. In the region lying between 77°48′S, 66°10′E and 77°28′S, 66°05′E, a marked change in the surface relief of the ice was noted. The monotonous level surface had become hilly, with domes and crevasses running irregularly. It was conjectured that hidden beneath the ice was a mountain mass and that its peaks came close to the surface of the ice.

A few days later, the Third Expedition's first train left Mirny. It was an impressive sight: ten powerful tractors, each with two sledges in tandem. The transport equipment of the Third Expedition was more advanced than that of the first two expeditions. The members of the First Expedition

had gone into the interior on tractors; the Second Expedition had had at its disposal caterpillar tractors and special sledges. But in each case, the tracks and runners were not wide enough, and the towing arms on the sledges to which the tractors were "harnessed", were weak and tended to break on sharp turns. The low oxygen level at the high altitudes in the interior caused incomplete fuel combustion in the tractor engines, thus reducing their power and increasing fuel consumption.

The tractors and sledges used by the Third Expedition had none of these shortcomings. They were fitted with wide tracks and runners, and the tractor engines were equipped with turbo-compressors to supercharge the air. The tractor cabins were bigger and more comfortable, with good heating and ventilation. Both the tractors and the sledges moved easily over the powdery snow, and fuel consumption was reduced.

The train heading into the interior carried 32 men. On January 2, 1958, it reached Pionerskaya, and arrived at Komsomolskaya on January 17. At the end of January, seven tractors and seven sledges made a trip to Vostok Station to deliver supplies and equipment. By that time, relief crews had been flown to the interior stations. After making its delivery at Vostok Station, the train returned to Komsomolskaya.

On February 3, an eight-tractor train left Komsomolskaya for the Pole of Relative Inaccessibility to establish Sovetskaya Station. After travelling a distance of 540 km, the train stopped on February 10, 1958, at a point with coordinates of 78°24′S and 87°35′E. It was here, at an absolute elevation of about 3,650 that Sovetskaya Station was established. Leaving five men at the station for the winter, the train headed back to Mirny and arrived there on March 5. All in all, it had covered a distance of about 4,000 km.

Besides the heavy tractors, the Third Expedition had at its disposal a number of lighter cross-country vehicles, which were dubbed "penguins". They were first used in January, 1958, for an experimental trip to Pionerskaya, and again in March, this time by a party of seismologists and glaciologists who made a field trip to the same station to study the temperature regime of the snow and ice mantle and the physical characteristics of the snow, and also to test a new apparatus for boring holes in the snow and to refine their methods of seismo-acoustical measurement.

Although this was not the first trip made by Soviet explorers into the deep interior of the continent, it did not proceed altogether smoothly, and working conditions were difficult. The towing attachments on the sledges would snap off because the cold made steel brittle, and they had to be repaired in the fierce wind and frost. Several stops had to be made to reinforce the steel pole of the boring device. At night, the tractors and sledges would become covered over with snow, and it was no easy task in the mornings to dig them out and get them moving again.

The picture of good progress looked something like this: "The tractors and sledges bounced on the sastrugi as if they were moving over the iron spikes of a giant overturned harrow. The steel pole shakes terribly; cups and saucepans fly about on the floor of cabin; our warm fur suits and hats barely protect us from getting bruised all over. But still we go on and on forward..." [121].

After an exhausting trip and much hard work in the desert, the researchers finally arrived at Pionerskaya Station. It was an interesting sight, for it was completely buried in snow, and the station director ran out to meet the "penguins" fearing that they might crush the huts hidden beneath the snow. "We climbed down a steep ladder below the surface of the snow. The men lived eight metres down. The ladder led to a chamber connecting two small houses. One of them held the living quarters, the radio-station room and a study. The other contained the kitchen, dining room and library. Several tunnels led away from the connecting chamber to various clearings where instruments were set up in niches..." [122].

The men that made the trip on the "penguins" settled about two kilometres from the station, where they established their own little village, Malaya Pionerskaya.

The winter in the interior was extremely harsh in 1958. The polar night set in at Sovetskaya on April 22, and at Vostok on April 28. On August 25, the lowest temperature, that had ever been observed on the Earth's surface, was registered at Vostok Station —87.4°C. At Sovetskaya Station at that time it was —76°C, and —81°C at Komsomolskaya.

The complicated trip to the Pole of Relative Inaccessibility, 2,100 km away from Mirny, was organised in spring of 1958. Members of the expedition have flown over the area, but without landing. So far, no man had ever set foot on this, the last unconquered pole.

The work all along the way involved measuring the thickness of the snow and ice, studying their physical properties and investigating the underlying rock surface. In addition, geomagnetic, gravimetric and meteorological observations had to be made. Finally, the expedition had to establish a research station in the deep interior of the continent, and for at least a short period of time conduct stationary observations there.

At the outset, it was decided to split up into two parties. The first party left Mirny at the end of September on "penguins". It had to stop for repairs several times during the first part of the trip and as it approached Pionerskaya, because the towing hitches kept breaking off. On October 10, the train arrived at Pionerskaya, where the winterers were still living under the snow. Members of the train party took specimens of the snow in the vicinity of the station. They worked when it was below —50°C and a strong wind was blowing, and thus hands and faces became numb with cold.

Part of the train column returned to Mirny while the rest of the "penguins" started out again on October 16, in the direction of Komsomolskaya Station.

Huge piles of snow, two to three metres high, built up by the wind, and sastrugi kept blocking their way. The towing hitches kept breaking under the strain caused by jerking. The metal suffered "fatigue", but the men worked tirelessly as they overcame metre after metre in their slow advance in the crumbly snow. In two days they covered a distance of only six kilometres. The train was covered with a whitish veil; visibility was almost zero. At every stop, the tractors, the sledges and the cabin of the drilling apparatus became covered over with snow.

At the end of October, they came to another area of crumbly, powdery snow and made a forced stop at the 705th kilometre. "Everyone is exhausted. Evidently the elevation (around 3,500 metres!) and the tremendous physical stress are having their effect. At least it is a good thing that the wind has died down and the snow storm and ground winds have disappeared. The sky above is bright, with a dark violet tint, and is covered with a thin film of wispy cirri. The temperature is still minus fifty degrees" [123]. On November 2, the party, having traversed 870 difficult and strenuous kilometres, arrived at Komsomolskaya Station.

On October 23, the second party left Mirny for Komsomolskaya. This train consisted of six caterpillar tractors, a "penguin", and sledges loaded with supplies, equipment and four cabins. The seismologists in the party measured the thickness of the ice sheet between Pionerskaya and Komsomolskaya. The glaciologists took observations of the temperature regime at various depths in the snow and névé mantles and analysed the snow crystals. The train arrived at Komsomolskaya on November 12.

There the two trains were reorganised. The tractors, food, fuel and spare parts were divided up between two teams. One took the "penguins" and headed for Vostok Station with a load of fuel and other supplies needed for the next winter, while the other set out with heavy tractors to Sovetskaya Station. This team was joined by the main party of scientists who had come to Komsomolskaya on "penguins". The train began its journey on November 20. At first, it proceeded easily, but soon it came upon an area of crumbly snow where the tractors moved with difficulty, leaving behind them ruts up to one metre deep. Great billows of snow piled up in front of the sledges. The train arrived at Sovetskaya Station on November 29. The structures at this station were not snow bound, for there is a much smaller snowfall in that area than around the edges of the continent.

At the height of preparations for the next and crucial leg of the journey, the head of the expedition, E. I. Tolstikov, flew in from Mirny. He took command of the next stage of the march to the Pole of Inaccessibility, in which 18 men took part.

The column moved out on December 3. "The tractors move forward, digging into the crumbly snow and leaving deep tracks as if plowing virgin soil. Indeed, this is virgin soil, where no man has ever set foot" [124]. It was already summer, but it never got warmer than —30°C, while at night the temperature would drop to —45°C! The train moved forward, slowly leaving kilometre after kilometre of the snow and ice desert behind.

Before long the party came to a gradual upgrade, and on December 8 reached its highest point, 4,000 m above sea level. The altitude had a marked effect on the men; each quick motion caused a shortage of breath, and everyone felt a dryness in the nose and throat.

Along the entire route—between Komsomolskaya and Sovetskaya stations and between Sovetskaya and the Pole of Relative Inaccessibility—meteorological, glaciological, geomagnetic and gravimetric observations were made and, most importantly, as was the case before getting to Komsomolskaya Station, the thickness of the ice cover was periodically measured by seismic sounding techniques. The maximum reading between Mirny and the Pole of Inaccessibility was 3,770 m. The soundings showed that in the central sector of East Antarctica the glacial bed lies above sea level almost everywhere. The only exceptions are the coastal regions and a few strips between Pionerskaya and Komsomolskaya stations. Beyond Komsomolskaya, in the vicinity of Sovetskaya and further on towards the Pole of Inaccessibility, seismic soundings revealed a large mountain massif buried under the ice. Its highest point, lying between Sovetskaya and the Pole of Inaccessibility (1,700 km from Mirny) rises to approximately three kilometres above sea level. In about this same area are also found the greatest heights of the glacial ice sheet surface (4,000 m). On the other side of the summit, as the surface gradually slopes downward, there is a corresponding marked sinking of the subglacial bedrock, which at the Pole of Inaccessibility is only 800 m above sea level.

Getting a cross-section of the glacial cover from Mirny to the Pole of Inaccessibility, including the first section through central regions of Antarctica, was a great achievement of the expedition and the major accomplishment of the trip to the Pole of Inaccessibility. It was the first time successful sounding had ever been made in the central regions of the ice continent.

The train reached the Pole of Inaccessibility on December 14. Everything around was monotonously white and desolate.

The party's navigator "pointing to a mount of snow that had been piled up by the wind at a sastruga, cried out, 'This is it! The last of the Earth's poles to be conquered'" [125].

After drinking in the joyous feeling that comes when a long sought-after goal is achieved, the explorers began the more prosaic tasks. They built a hut for the station, set up a meteorological platform and sent the first weather report by radio from the Pole of Inaccessibility.

On a high pedestal they placed a bust of Lenin, and after a brief ceremony, raised the flag of the USSR. At that moment a hearty "Hurrah" resounded, and multi-coloured rockets shot into the air. At a point 2,100 km from Mirny, at 82°06′S and 54°58′E and at an absolute elevation of 3,720 m, the temporary research station, named the Pole of Inaccessibility, was officially opened.

It might be noted that besides the south geographic pole, several other poles are singled out in Antarctica: the magnetic, the geomagnetic (where Vostok Station was established) and the Pole of Relative Inaccessibility. To these there may also be added the Earth's wind and cold poles, both located in Antarctica.

The point at which the new station was established actually ceased being the Pole of Inaccessibility since it had been reached and settled for a time by the Soviet explorers. It would perhaps be more correct to call it the geographical or geometric centre of the continent. However, this point is more difficult to reach by any means of transportation whatever than any other point in Antarctica, and therefore it still makes sense to call it the Pole of Relative Inaccessibility.

Here, at the centre of the ice continent, over a period of two weeks at the final stage of the IGY, stationary scientific observations were conducted. On December 19, a plane from Mirny landed on the strip that had been cleared near the station. It came to pick up the leaders of the expedition, the team of scientists who were to turn over their work to their replacements—the leaders of the Fourth Soviet Antarctic Expedition and its units—who had already arrived at Mirny. The train left the Pole of Inaccessibility on December 26, and reached Mirny on January 18, 1959.

At the end of September 1958, E. I. Tolstikov, the leaders of the aerometeorological and geophysical units and other members of the expedition made a flight on a plane commanded by V. M. Perov to the Australian Mawson Station. The return flight was interesting, when instead of flying along the coast they flew over the continent to determine the glacial heights. At 68.05°E, some 250 km inland from the coast, the mountains in the Prince Charles Range were almost devoid of snow cover. Between the peaks could be seen high altitude lakes and frozen streams connecting them. Then the plane flew over a region where, according to an

American map published in 1957, there were supposed to be "mountains discovered in 1939 by Lincoln Elsworth". However, no such mountains were spotted. Visibility at the time was excellent, so it became clear that the American's information was erroneous.

On October 24, 1958, in the same plane, commanded by Perov, Tolstikov and other members of the expedition made a flight over the route, Mirny—Sovetskaya—South Pole—the US McMurdo Station. Throughout the flight, readings of the atmospheric temperature and pressure and the plane's altitude were taken, which made it possible to determine the height of the glacier surface along the line of flight. Flying low over Amundsen-Scott Station, the plane became the first Soviet aircraft to fly over the South Pole. In a little under 14 hours after leaving Mirny, the plane landed at McMurdo Station. On October 26, it returned to Mirny via the polar route in a little over eight hours.

Some interesting discoveries were made on December 7, 1958, during the second reconnaissance flight from Mirny to the Pole of Relative Inaccessibility. The return flight passed through a place where no plane had ever flown before. It was discovered that at 75°12′S, 61°00′E, there stood a theretofore unknown pyramidal mountain, half covered with snow, with an absolute elevation of about 3,300 m. The flight party saw another 17 summits along parallel 74°S, between 66°00′ and 63°30′E. At 74°10′S, 63°21′E was a massive two-peaked mountain, and six uncharted peaks were discovered near 73°45′S between 64°20′ and 66°00′E. They also discovered two groups of nunataks* not shown on any map. In the vicinity of Princess Elizabeth Land they found two glacial domes, and flew to the west of them over the beginning of an unknown glacier situated in the hollow of an ice sheet.

At the height of the IGY (1958), seven Soviet stations were operating in Antarctica. While the Pole of Inaccessibility Station functioned for a relatively short time, the others—Mirny, Oasis, Pionerskaya, Komsomolskaya, Vostok and Sovetskaya—carried out a year-round or almost year-round (at Sovetskaya and Oasis) programme of observations.

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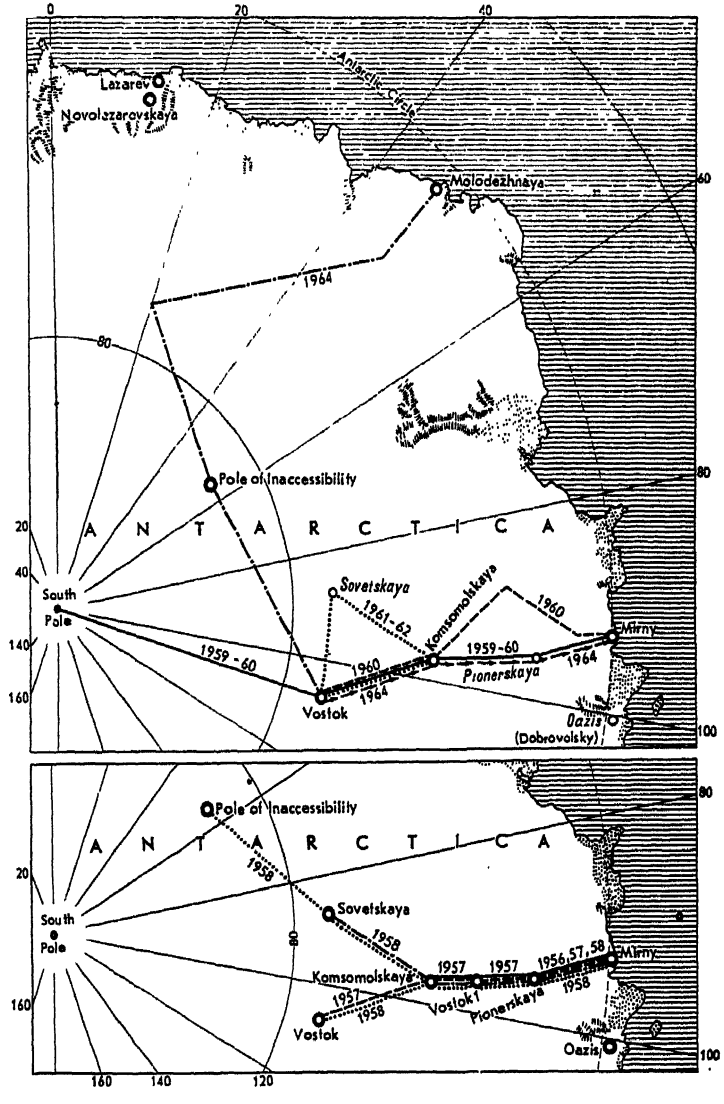
* A nunatak is a hill or mountain completely surrounded by glacial ice.



Soviet research stations in Antarctica and the main tractor and sledge train routes between 1956 and 1964

The lower map shows routes and stations during preparations for the IGY; the upper map shows routes and stations after the IGY. The larger circles indicate permanent and temporary stations operating during the given period; the smaller circles (with station names in italics) indicate stations that are no longer functional after the IGY

At the end of the IGY some of the stations were dismantled. Oasis Station was closed down temporarily. Its buildings and equipment were transferred in 1959 to Polish explorers (they named it Dobrovolsky Station), who planned to use it for conducting regular observations beginning in 1960. Their plan, however, did not materialise. Sovetskaya Station was closed down temporarily in the beginning of 1959, and Pionerskaya, in the middle of January. After 1959, Komsomolskaya Station went over to seasonal operations.

The *Ob*'s third voyage in the antarctic waters began on January 10, 1958. The Third Marine Expedition, headed by V. G. Kort, had 95 persons working in its various units. The expedition discovered many new geographical objects and determined their exact location. Many of these were named after Soviet geographers, while others were named after Soviet ships. In 1958, and in 1961, charts were published of the entire coastal zone of East Antarctica that had been studied from aboard the *Lena* in 1957, and from aboard the *Ob* in 1958. On February 10, 1958, the air photography of the coast was finished at 166°E and the *Ob* left the antarctic waters, heading for Wellington.

CHAPTER 13

FURTHER EXPLORATION OF ANTARCTICA

...Antarctica! The Earth's great ice sheet. There are no riches of generous Nature here; the great ice hides only danger, and its secrets so far attract only men of science.

M. A. Kuznetsov

The IGY programme of antarctic research ended in 1958. However, the Special Committee for Antarctic Research, at a meeting in Moscow in August 1958, decided the IGY programme of antarctic research should be extended. At the meeting, the Soviet delegation presented the planned work project of the Fourth Soviet Antarctic Expedition (1958-1960). The expedition was to be headed by A. G. Dralkin, a Soviet polar explorer who had twice worked on the North Pole 4 drifting station.

On December 30, 1958, the *Ob*, carrying members of the new expedition, arrived at the Mirny road for the fourth time. Arriving shortly thereafter was the passenger motor ship, the *Mikhail Kalinin*. At the end of January 1959, after unloading was finished and the switch in expedition personnel was made, both ships left Mirny, the *Mikhail Kalinin* taking the members of the Third Expedition home, and the *Ob* heading west along the antarctic coast. On board the *Ob*, in addition to a small oceanographic detachment, was the personnel that would man Lazarev Station, which was to be established on the coast in Queen Maud Land in an area called Princess Astrid Coast.

The *Ob* reached Princess Astrid Coast on February 10, 1959. This part of the antarctic coastline had been little

studied, but it was here that the ships of Bellingshausen and Lazarev's First Russian Antarctic Expedition in February 1820 had come almost right up to the big ice shelf which the Fourth Soviet Antarctic Expedition was to name Lazarev Glacier. Any doubt that Russian seamen had seen the continent proper at this place could have arisen only due to the inaccuracy of the maps of this part of the coast. But now the map error was spotted immediately. It turned out that the western edge of the ice shelf "was located not at 11°E, as shown on the map, but at 13°E, that is, 90 kilometres further east.... If the correct position of the glacier, as we (the Fourth Expedition—*N.G.*) have determined it, is shown on the map, it is easy to see that the Russian sailing vessels passed very near its northern edge, especially when account is taken of the probability that in the intervening 140 years, the edge of the glacier may have shifted a little to the south due to the breaking off of icebergs. Thus, Russian seamen had sighted the icy coast of the sixth continent once more after January 16 (1820—*N.G.*)" [126].

As soon as the *Ob* tied up to the fast ice near the Lazarev Ice Shelf, members of the expedition made reconnaissance flights in a helicopter and a light airplane to find a suitable spot for the station. These was no bedrock showing anywhere so it was decided to build the station right on the tongue of the ice shelf not far from where the *Ob* was moored, one and a half kilometres from the ice barrier.

A fierce hurricane, with winds up to 70 m per second, came up as the ship was being unloaded. The fast ice broke up and got carried away. Despite frantic efforts to save the supplies and equipment on the ice, a bulldozer, a cross-country vehicle, four tractors, eight metal sledges, a large quantity of fuel and other supplies and part of the scientific equipment were lost. An especially serious loss, however, was the helicopter that had already been used but was on the fast ice at the time. Fortunately, some tractors that had been shipped from Mirny for repairs were still on board. The drivers and ship's mechanics put them into working order, and the unloading was resumed. Two days later it had to be halted again because of another hurricane. The weather improved at the end of February and the job of unloading was completed. Soon all the station buildings were set up. On March 10, 1959, the flag of the USSR was raised and a brief ceremony held, officially opening Lazarev

Station, named after M. P. Lazarev, who commanded the sloop *Mirny* in the First Russian Antarctic Expedition.

The mooring of the *Ob* at Princess Astrid Coast and the establishment of Lazarev Station played a big role in ensuring geological explorations of the Antarctica's biggest mountains, stretching almost 1,000 km latitudinally and rising above the surface of the glacial ice to an elevation of 1.5 to 2 km.

Most of the mountainous region in Queen Maud Land, including the areas explored by the Soviet geologists, had never before been visited by man. The use of the airplane and helicopter enabled the explorers to cover a large area in a short period of time. Ten sectors of the mountain mass were explored; these lay in the Wohlthat and Humboldt massifs, the Russian Mountains and in the Schirmacher Oasis.

On February 12, during a reconnaissance flight inland, between the Wohlthat and Sor Rondane massifs, "scores of new mountains, not indicated on any map, were discovered, subsequently to be named the Russian Mountains" [127]. This discovery took place when the plane was transporting a team of geologists, headed by M. G. Ravich, to a camp that had been set up for them. During the flight, careful observations of the relief were made.

Some jagged mountains appeared on the horizon. "They got bigger and bigger every minute. Big brown hulks of cliffs with white snow caps grew before our eyes. Soon the mountains, separating the coast from the glacial dome of the continent, stretched along the entire horizon. Above the light blue ice rose almost vertical rock walls, ending in needles tens of metres high" [128].

The plane flew along the length of the mountains. From above, blue frozen lakes could be seen at the bottom of gorges. The plane dropped down to a section of moraine and landed on the ice. The geologists pitched their round black tents on the moraine boulders—"the first human dwelling in the eastern half of Queen Maud Land". "You can't tear your eyes away from the patterned chaos of the mountain peaks, so unusual in icy Antarctica," wrote M. G. Ravich.

In the following days, the plane made several flights over the area, landing on the ice and bringing the geologists to the foot of individual peaks in the newly discovered Russian Mountains. They named one of the peaks after geolo-

gist Karpinsky, and another in honour of paleontologist Yakovlev.

Later, the geologists made flights to the Humboldt Mountains and the Conrad Range. The Humboldt Mountains, as well as the Wohlthat Massif in the Queen Maud Land mountain system, had been photographed by a German expedition (1939); however, the German explorers saw the Conrad Range only from a distance.

"The plane flies around the slopes of mountains that lift their peaks to a height of 4,000 metres above sea level. The mountains envelop ice valleys 10 to 15 kilometres long, along the bottoms of which are great flowing streams of rock—the massive glacial moraines. Framed in light blue ice are peaks of the most diverse forms, hues, structure and heights, creating unforgettable pictures of the antarctic mountain landscape. Rocky walls, 300 metres high, are split by faults. The steep peaks stand out like the teeth of some fantastic monster against the background of rounded or flattened summits.... It is hard to imagine just such fantastic rock and ice structures anywhere else in the world" [129].

After two more landings, the geologists flew to Schirmacher Oasis, 85 km south-west of Lazarev Station. It resembled Bunger Oasis, but was much smaller. This was a narrow (up to two kilometres) strip of rocky hills stretching for about 15 km along the border between the continental and shelf glaciers. Among the hills, which were no more than 200 m high, beautiful frozen lakes showed blue in hollows at an elevation of 60 to 70 m above sea level. On the slopes heated by the sun could be seen spots of blue-black algae and emerald green mosses. Snow petrels and skuas were nesting on the rocks.

On March 11, 1959, the day after Lazarev Station was officially opened, the *Ob* set out to sea, heading for the southern tip of Africa. On board was a hydrological team, which conducted hydrological and ice observations during the voyage. An oceanographic traverse was made, consisting of 15 deep-water stations along the meridian 20°E. The geological team also returned home on the *Ob*.

Seven men stayed to spend the long winter at Lazarev Station. Their job was to gather the first data on this part of the antarctic coast that had greeted the Soviet researchers so harshly.

By the time Lazarev Station was opened, the houses of the new Soviet antarctic settlement were covered almost to the roof tops with snow as a result of a blizzard that was raging on the coast. Enclosed passage ways were made between all of the station's buildings so that the winterers could get to any of them without going out into the wind and cold. Hurricanes and blizzards raged for 17 out of the 28 days of February. Throughout the winter, there were 141 days of storms, 52 of which were of hurricane intensity. The station was completely snow bound; the only way to get outside the buildings was through trap doors in the roofs. The men at the station conducted systematic meteorological, actinometric and magnetic observations, sent up radiosounders and studied the snow build-up and the structure of its top layer. With a thermodrill they melted a hole in the ice to a depth of 37 m in order to keep the temperature of the ice below the surface under constant observation.

In the spring, the winterers began to make excursions around the vicinity of the station. They found that the edge of the Lazarev Ice Shelf was undergoing intensive destruction: big chunks of ice were breaking away from the ice barrier and turning into icebergs. The station, only 1.5 km from the edge of the ice shelf, was not in a very safe location. Nine kilometres to the south-east, the men set up a reserve station—a tent with emergency equipment and food.

The Fourth Soviet Antarctic Expedition had certain kinds of scientific instruments and equipment that its predecessors did not. For making trips inland it received new specially constructed powerful snow tractors with hermetically sealed cabins supplied with the latest in equipment. They could tow heavily laden sledges under conditions when temperatures were low and the air rare. Their only drawback was their high fuel consumption. On February 10, 1959, three such snow tractors with sledges in tow set out from Mirny for Komsomolskaya. When the train arrived 17 days later, the tractors were left there till spring, and the train crew was flown back to Mirny. This delivery was made in preparation for the long haul to the South Pole.

A "penguin" trip was organised with the aim of making a geodetic levelling of the ice dome from the coast inland. The weather conditions during the fall and winter stage of this trip (April 9-June 25, 1959) were very bad, with almost incessant snow storms, strong winds and temperatures of

—40°C and lower. The blizzards and zero visibility prevented the train from moving at all 51 days out of the 78. Nevertheless, the party succeeded in carrying out 56 comprehensive geodetic stations and in conducting a large number of meteorological, glaciological and general geographical observations.

During the spring and summer stage of the "penguin" trip (September 14-December 31), the levelling of the ice dome was continued in the direction of the former Pionerskaya and the Komsomolskaya stations. Despite the fact that it was spring and summer, the party ran into great difficulties even at this stage because of highly unfavourable weather conditions along the way. The party was actually able to work only 45 days out of the 109 they were en route; but they managed to carry out observations at 203 comprehensive stations and cover a distance of 870 km.

One of the results was that the absolute elevations at which Pionerskaya, Vostok-1 and Komsomolskaya stations stood were determined for the first time by the geodetic levelling method, and this was most important for processing and analysing all observations made earlier at those stations.

On October 20, a reconnaissance flight, during which air photographs were taken, was made to the northern slopes of the Queen Maud Land mountains and to the lakes in the Schirmacher Oasis. On October 26, a similar flight was made to the pass between the Wohlthat and Sor Rondane massifs (also in the Queen Maud Land mountain system). Near Mt. Peier the plane turned east. "A few minutes later on our right we saw mountains that were not on the map. As we came closer we counted seven of them. Straight ahead was another big mountain, and next to it two others, considerably smaller in size and height" [130]. Photographs of the new mountains were taken from the airplane.

The culmination of all the work done by the Fourth Soviet Antarctic Expedition in the IGY programme was the trek to the South Pole. The main objective was to continue measurements of the ice thickness in the internal regions of East Antarctica and to combine into a common system the traverses carried out by Soviet, American and British expeditions.

At the end of September, an auxiliary train consisting of five tractors and trailers departed from Mirny for Komso-

molskaya, hauling fuel for the forthcoming trip to the South Pole. It arrived at Komsomolskaya on October 19. Travelling with the train, besides the drivers and the scientific workers who were to take part in the new trip to the pole, were the men who were assigned to staff Komsomolskaya Station, which on that day, after a long interval, was put back into operation. The minimum thermometer that had been left at the station in March showed that during the winter of 1959, the temperature there had reached an absolute minimum of —84°C.

Upon arrival at Komsomolskaya, the party began preparing the snow tractors that had been left there previously. The men had to work in frosts as low as —68°C.

On November 6, the train, consisting of five tractors (three of which were the new snow tractors) and eleven sledge trailers, started out from Komsomolskaya on its way further inland. Between Komsomolskaya and Vostok stations, the train was under the command of B. A. Savelyev, the head of the glaciological team.

At a point about 100 km from Komsomolskaya, it ran into an area of loose, crumbly snow. The tractors sank deep into the snow, and the sledges scooped up huge piles of snow in front of them, which slowed down their movement considerably. The strain caused a number of breakdowns; much time had to be spent replacing broken pins and tracks. The train covered an average of 24 km a day, but some days it advanced no more than ten kilometres. The train arrived at Vostok Station on November 29.

Between Komsomolskaya and Vostok, a distance of 540 km, the men made three stations at which they measured the thickness of the ice sheet, determined the level at which the bedrock lay, checked the force of gravity and took various kinds of observations of the snow and ice cover. The thickness of the ice everywhere was about 3,000 m. Below the ice sheet at approximately sea level, was a plain, although in some places the bedrock rose 100 to 200 m above it. Under Vostok Station, the ice was 3,700 m thick.

At Vostok, the equipment selected for the final leg of the journey to the South Pole was serviced. Although according to the calendar it was already summer, the temperature was still as low as —50°C. And the absolute elevation there was 3,416 m! "Examining the caterpillars, changing the pins and tracks, switching trailers, securing the

loads on the sledges and many other jobs could be done only in the open air. The men's hands and faces got frosted over and work was exhausting due to oxygen deficiency. At the end of a hard work-day, the drivers would literally collapse from fatigue" [131].

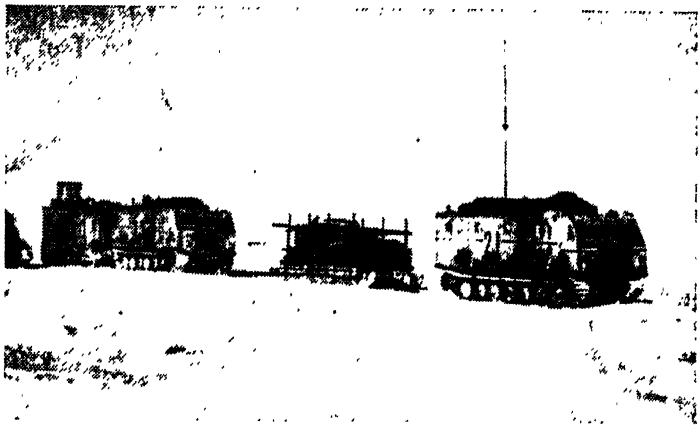
The South Pole train, consisting of three tractors—two snow tractors and one tractor with a built-in electric galley—and four sledges, pulled out from Vostok Station on December 8, 1959, with 16 men. The lead tractor headed towards the South Pole along the meridian 106°E. "The way ahead lay through completely unexplored regions of Central Antarctica that had never even been flown over by plane. What awaited ahead no one knew," wrote A. G. Dralkin, the leader of the party. "We were heading into the unknown, further and further from our base—from Mirny, and from Komsomolskaya and Vostok stations" [132].

At a point 200 km from Vostok Station, they conducted a series of observations and every 200 km after that they stopped for the same purpose. They would tow the sledge carrying the glaciological equipment a short distance away from the other machinery. There they would bore a hole 50 to 60 m deep to measure the temperature of the various layers of snow and ice and to determine the density of the ice at different levels. After that, they would use the hole to measure the thickness of the ice and the depth of the underlying bedrock. The measurements showed that further along towards the South Pole, lying under three kilometres of ice, is a slightly hilly plain, largely at sea level, with rises here and there of only 100 to 200 metres. The weather was relatively good and the train covered 90 to 100 km a day.

To lighten the load and thus increase their speed, the explorers set up several intermediate bases where they left fuel for the return trip. They marked the points where they left fuel and extra sledges by piling up empty barrels. The next to the last stop for scientific observations was made 90 km from the pole.

They reached the South Pole and the US Amundsen-Scott Station on December 26, 1959. "I had the honour of raising our flag at the South Pole," writes A. G. Dralkin. "It was up throughout our stay there."

On December 28, all the members of the party accomplished the traditional round-the-world journey: in a matter of 15 minutes they drove around the South Pole in a circle marked



A tractor and sledge train of the Fourth Soviet Antarctic Expedition at the South Pole

by empty barrels. They received special diplomas commemorating that trip.

At the pole, the Soviet travellers were guests of the American researchers who met them at Amundsen-Scott Station and showed them all around the station. In addition, the Soviet scientists conducted some research work there themselves. Seismic probes showed that the bedrock at the South Pole is at sea level and that the thickness of the ice cover is 2,810 m.

The average thickness of the glacier between Komsomolskaya and the South Pole was about 3,200 m. The greatest thickness was found at Vostok Station (3,700 m).

On December 29, after making a farewell turn around the pole, the train set out for the south geomagnetic pole, that is, back to Vostok Station. The empty barrel stacks at different points along the way could easily be seen from a distance of several kilometres and served as excellent landmarks. The tracks left from the trip up could also be seen. The return to Vostok Station took 13 days. The entire journey lasted 103 days, from September 27, 1959, to January 8, 1960, during which a distance of about 4,000 km was traversed. At Vostok Station, the tractors were weatherproofed and the party was flown to Mirny.

The South Pole trip yielded data on the following: the elevation and nature of the surface of the antarctic ice dome

for a distance of 1,826 km between Komsomolskaya station and the South Pole; the elevation above sea level of the underlying bedrock and the nature of its surface, and the distribution of gravity and elements of the Earth's magnetism, all over the same distance; between the south geomagnetic pole and the south geographic pole for a distance of 1,286 km, the distribution of the density of the snow and névé layer from the surface to a depth of 50 m.

The work done by the Soviet Union during the IGY and the year of international co-operation was continued by subsequent Soviet expeditions in accordance with the International Antarctic Treaty.* After this Treaty was signed—an event of great scientific and political importance—Antarctica came to be called the continent of science and peace.

On December 19, 1959, the *Ob* returned to the shores of Antarctica near Lazarev Station. On board were part of the personnel of the Fifth Soviet Expedition, headed by E. S. Korotkevich (who had been a member of the First Expedition) and the relief personnel for Lazarev Station. Returning on the *Ob* was the team of geologists that had begun exploring the mountains of Queen Maud Land the previous season.

Once the geologists were landed, the cargo unloaded and the exchange of personnel at Lazarev Station made, the *Ob* sailed along the coast to the east towards Mirny. By January 14, 1960, she was at the fast ice of Pravda Coast, and on January 25, she broke through the fast ice making a channel to the unloading point. Through this channel the *Ob* led the motor ship, the *Kooperatsia*, which had tied up to the fast ice in the Mirny area on January 7. A large part of the Fifth Expedition's personnel had come to Mirny on the *Kooperatsia*. Because of the fast ice along Pravda Coast, the ship stopped 20 km from Mirny and communication with it was maintained by airplane. The leaders of the various detachments, the senior specialists and the new personnel for Vostok Station were flown from the ship to Mirny.

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* The Treaty was drawn up at a special conference on Antarctica, held in Washington, D. C., in the autumn of 1959. The conference, attended by the 12 nations that had co-operated in the IGY endeavour, culminated in the signing of the Treaty on December 1, 1959. The text of the Treaty can be found in books by A. V. Noudelman and A. F. Treshnikov [133].

On February 1, 1960, the *Ob* and the *Kooperatsia* left Mirny road, the *Kooperatsia* taking the members of the Fourth Expedition home, and the *Ob* heading east with a small oceanographic detachment.

On March 10, 1960, the *Ob* came up to Peter I Island. Taking advantage of the favourable weather, the oceanographers circumnavigated the island and recorded a detailed description of it. They then sailed to Cape Horn, ending their navigation of the antarctic waters. The *Ob* had covered a distance of over 8,400 miles along the antarctic coast south of 60°S, with more than half that distance lying south of 65°S. "No one had ever before made such voyages around Antarctica" [134].

The wintering contingent in 1960 consisted of 129 men. Disaster struck the Fifth Soviet Antarctic Expedition that year. On the night of August 3, a hurricane burst in the Mirny area, with winds up to 56 m per second. As the hurricane raged, a fire broke out in the house where the aerometeorological detachment was lodged. The fire took the lives of the leader of the detachment, O. G. Krichak; weather forecaster A. M. Belolikov; aerologists I. A. Popov, V. I. Samushkov and A. Z. Smirnov; meteorologist A. L. Dergach; aerologist K. Oldřič (Czechoslovakia); meteorologist G. Popp (German Democratic Republic).

In February-March and at the end of 1960, two trains went inland from Mirny, one to Komsomolskaya Station and the other to Vostok Station. The second train followed a route to Komsomolskaya that went further west than usual and conducted seismoacoustical, glaciological and gravimetrical observations along the new traverse. The data gathered confirmed the accuracy of previous measurements of the thickness of the glacier and supplemented them. The seismic and gravimetric observations confirmed previous conclusions regarding the platform structure of East Antarctica and regarding the presence of subglacial mountain massifs.

On December 31, 1959, the geological detachment of the Fifth Expedition pitched camp on the north slope of the Conrad Range (in the Queen Maud Land mountain system), and began its research activity on January 1, 1960. Later, the geologists moved 200 km west along the northern edge of the Queen Maud Land mountains to set up a camp at 5°E. They discovered new geological formations and completed

a geological field map, with a scale of 1 : 2,000,000, of a considerable area of the mountain territory of Queen Maud Land.

The winterers at Vostok Station gathered interesting meteorological data of fundamental importance for characterising the climate of Antarctica and of the entire planet. On August 24, 1960, that is, in the second half of winter, an absolute minimum temperature of —88.3°C at the Earth's surface was registered, giving Vostok Station the reputation of being the coldest place on Earth, i.e., the Earth's pole of cold.

The Sixth Soviet Antarctic Expedition (1960-1962) — under the command of V. M. Driatsky — established a new first-class observatory in the Queen Maud Land region (Princess Astrid Coast). It was named Novolazarevskaya Station. Lazarev Station's being on the edge of an ice shelf involved a certain amount of risk. Concern about that station increased when depth measurements in the gulfs of the Lazarev Ice Shelf showed that the ice under the station was afloat and that there was a trench with depths of over 700 m in the vicinity of the station. It was decided to move the station to a new and safe place. But what had to be done, essentially, was to build a new station, since the buildings at Lazarev Station were snow bound and had frozen solid to the underlying ice. It was senseless to try to dig them out and disassemble them. So it was decided to build a new station at the Schirmacher Oasis.

After the *Ob* arrived at the Lazarev Station road (December 11, 1960), a team of glaciologists used two cross-country vehicles to make a road going from the barrier of the Lazarev Ice Shelf to the Schirmacher Oasis—a distance of 80 km. The road was then used for hauling building materials and equipment for the new station.

Set up on the rocky cliffs of Schirmacher Oasis were three Shaposhnikov houses, four prefabricated houses, an aerological pavilion, a glaciological pavilion, three pavilions for geomagnetic observations, and auxiliary premises. Novolazarevskaya Station began operation on February 18, 1961.

The station's programme included meteorological, actinometric, aerological, glaciological and geophysical (Earth's magnetism, polar lights, etc.) observations.

The Sixth Expedition included a seasonal geological detachment headed by M. G. Ravich, which joined in the

work of the Fifth Expedition's detachment. Up to February 24, 1961, the two detachments, which had at their disposal three light airplanes, continued the geological investigation of the Queen Maud Land mountains at 803 points, simultaneously taking air photographs of the entire area under study. The mountain area was subjected to geological examination and the basic features of its relief were ascertained. Various kinds of minerals were discovered.

A small oceanographic detachment took part in the *Ob*'s sixth voyage. It carried out a total of 97 deepwater hydrological stations in the coastal waters between the Lazarev and Shackleton ice shelves.

A total of 112 men wintered at three Soviet Antarctic bases (Mirny, Vostok and Novolazarevskaya) in 1961. It was the fourth wintering party for Vostok Station. Komsomolskaya Station, which normally operated in the summer season, had been closed up in March 1961 for the winter, but began operating again in October. Trains went there from Mirny to deliver fuel, and at the end of October, a team of geodesists were flown there with the aim of continuing the precise determination of the elevations of the antarctic ice dome begun by the Fourth Expedition. The Fourth Expedition had left there two "penguins" and the equipment needed for geodetic levelling.

A geodetic train made up of two "penguins" with geodetic equipment and one tractor, set out from Komsomolskaya on November 12, 1961, in the direction of Sovetskaya Station. The cross-country vehicles, from which the geodetic measurements were made, took turns in moving from point to point, always keeping each other within sight. Each time the measurements were taken, the rear vehicle would pass the one ahead and stop about 10 or 11 km further on, always keeping an average of 5.5 km between the two as the geodetic measurements were being taken. At the same time, systematic gravimetric, magnetometric and meteorological observations were taken. Working with precision instruments in the extreme cold was not easy; the temperature then, even in the summer, went as low as —40°C.

In the first days of December, the geodesists' train arrived at Sovetskaya Station, which had been shut down in early 1959. On December 6, it started out towards Vostok Station over a new route and arrived there on December 21.

It now remained to close geodetic routes along the third side of the triangle, namely, from Vostok to Komsomolskaya. This was done between December 26, 1961 and January 11, 1962.

In December 1961, the First Soviet Air Expedition set out for Antarctica. This was an experimental flight, regarded as an important step in the development of transportation links between the USSR and Antarctica.

The expedition took off from Moscow's Sheremetyevo Airport on December 15, 1961. On board the two big IL-18 and AN-12 turboprop airplanes were, besides the flight crew, meteorologists, aerologists, glaciologists and a group of journalists. Aerometeorological observations were conducted continuously throughout the flight.

The first part of the 25,000-kilometre flight followed the usual Aeroflot and Air India Moscow—Tashkent—Delhi route. Then the planes flew the air routes of certain foreign airlines through Burma, Indonesia, Australia and New Zealand. The final leg of the journey was over an unbeaten track, as it were, since there was no regular air service between New Zealand and Antarctica. From Christchurch, New Zealand, the planes headed for McMurdo Sound, where at 78°S the airfield of the US McMurdo Station was located.

The IL-18 was in the lead. As it reached the latitude on which Mirny lay, the ice mountain peaks of Victoria Land could be seen. Below and to the left was Ross Sea, and to the right was the antarctic mainland. "Everyone was at the windows. There it was, the mysterious, inaccessible land, dressed in its icy armour and shining so blindingly in the bright rays of the summer sun that it hurt to look at it without dark glasses. Gigantic glaciers could be seen flowing down from the continent into the sea. In some places they ended in sheer walls. These were the points at which icebergs floating there in the water had broken off" [135].

The weather was good, and both planes landed at the American base on December 24, without trouble. On the next day, the AN-12 took off again for Mirny; the IL-18 left for Mirny on December 27.

During their stay in Antarctica, the planes made several flights from Mirny to Vostok and over other routes. The seismoglaciological team of the air expedition made prep-

arations at both Mirny and Vostok stations for a sledge and caterpillar trip.

Both planes took off on the night of January 25, 1962, flying from the Bunger Oasis area to Christchurch. From there, they flew the same route they had followed on the flight in and arrived in Moscow in the beginning of February.

The skill of the flight crews working under the difficult conditions of ultra long-distance flight received special commendation from the Soviet Government.

The Seventh Soviet Antarctic Expedition (under A. G. Dralkin) did most of its basic work in 1962. That year, Vostok Station was closed down (for a year), but a new station, Molodyozhnaya, was established in Enderby Land near Alasheyev Bay. The party at that station and the members of the expedition's marine detachment (on the *Ob*) conducted meteorological observations for the purpose of studying the climatic regime of this little-explored region. Observations were conducted between January 9 and March 30, 1962, after which the station was sealed up.

A geological survey was made in the area around Alasheyev Bay, and oceanographic investigations were conducted of the coastal waters, including depth soundings and observations of variations in the water level.

The expedition continued research work at Novolazarevskaya Station, as well as at Mirny and south of Mirny.

In November 1962, the *Ob* left Leningrad for her eighth voyage to Antarctica. She was followed by the motor ship *Estonia*. The ships carried the members of the Eighth Soviet Antarctic Expedition, including its commander M. M. Somov and both the seasonal and wintering personnel. The basic task of this expedition was to prepare the antarctic stations for conducting expanded observations in the International Year of the Quiet Sun (IQSY) programme.* The work involved continuing year-round observations at the Mirny and Novolazarevskaya observatories; conducting seasonal observations at Komsomolskaya; resuming year-round observations at Vostok; establishing a permanent Molodyozhnaya Station to replace the temporary installations set up by the Seventh Expedition, and beginning year-round

* Officially, IQSY was from January 1, 1964 to July 1, 1965.

meteorological and hydrological observations there. The seasonal staff had also to continue the geological and geographical explorations in Enderby Land and to conduct oceanographic observations in the antarctic waters and on the way to Antarctica.

Hurricane winds and massive ocean swells caused frequent interruptions in the unloading of the *Ob*. The time lost in unloading was used for making oceanographic investigations and soundings in Alasheyev Bay.

There was such a blinding blizzard at Novolazarevskaya Station that the tractor and sledge train that set out to meet the *Ob* got lost along the 100 km stretch. It finally reached the *Ob* only by virtue of radio directions given from aboard the ship, where the train's movement was tracked by radar. The men on the train could see the spotlights shining in their direction from the ship only when they were already 250 m away. "It was impossible to hoist the tractors aboard, therefore for greater safety, they were driven 350 m away from the ship. The drivers returned to the ship by following a rope that had been thrown from the ship and tied to the train. During the night a large area of the fast ice began to break away, and by morning, one tractor had disappeared from the radar screen. It had gone under" [136].

From the Novolazarevskaya area, the *Ob* headed for Enderby Land to render aid to a geological detachment that had been hit by a fierce hurricane in the mountains by Richardson Lake.

It was March 1963. On the evening of the 12th, the wind at the geologists' camp on Richardson Lake increased and during the night the gusts attained hurricane force. Winds of over 60 m per second severely damaged their AN-6 aircraft, ripped the canvass trimming of their tents and pulled out and broke a number of aluminum tent supports. Some of the tents were blown away, but the men quickly repaired those that were left. They threw rope nets over the tents and fastened them firmly to rocks frozen in the ice.

On March 14, the wind died down, but soon the hurricane burst again with even greater force. By the morning of March 16, despite all the precautions taken, their second airplane was mangled, and the tents containing equipment and food supplies were ripped loose and scattered over the frozen lake. Everything was in movement. "Pieces of air-

plane, plywood panels and boards were flying through the air, and crates with food, gas cylinders and petrol drums were tumbling over the ice" [137].

The geologists barely managed to make their way to the foothills and find protection behind some boulders. They spend the night of March 16 to March 17 under the open sky. Their only means of communication remained behind in the damaged airplanes. Towards the evening of March 17, they succeeded in knocking together a temporary shelter behind a big boulder out of plywood panels. When the hurricane died down, a plane landed on Richardson Lake, and on March 19, evacuated the geologists to Mirny.

Observations were conducted throughout the *Ob*'s voyage. They included oceanographic observations (48 deep-water stations, observation of the surface currents and water temperature), biological and geological observations, and depth soundings.

The seasonal construction crew set up installations for a permanent Molodyozhnaya Station: two prefabricated houses, a temporary electric power station, food warehouses, a radio station and a meteorological station. The foundation was laid and building materials brought in for two panel houses. Molodyozhnaya Station began operating on January 14, 1963, and was manned by a team of eight.

The Eighth Expedition reactivated Vostok Station, which had been temporarily sealed up during the previous season. A tractor and sledge train was sent inland in January-March 1963 to get Vostok Station ready for uninterrupted work on the forthcoming IQSY programme. Some supplies and equipment were also brought in by air. In the meantime, Komsomolskaya Station had already been reactivated with the help of air transportation.

Wintering parties conducted systematic observations at the Mirny observatory and at Vostok, Novolazarevskaya and Molodyozhnaya stations. The comprehensive research carried out by the Eighth Expedition made a substantial contribution to our knowledge of Antarctica.

It should be noted that after 1963, the functions of organising antarctic explorations were transferred from the Ministry of the Merchant Marine of the USSR, under whose jurisdiction the Chief Sea Route Administration came, to the Chief Hydrometric Services Administration of the Council of Ministers of the USSR, under whose jurisdiction

the Arctic and Antarctic Research Institute in Leningrad was also placed.

On January 1, 1964, a new stage in the exploration of Antarctica began—the International Year of the Quiet Sun. The observations in the IQSY programme were handled by the Ninth Soviet Antarctic Expedition, which, however, also continued a number of investigations not directly connected with that programme.* Unlike the previous years, the personnel of this expedition were brought to Antarctica not only by ship, but also by air. For this purpose, a Second Soviet Air Expedition to Antarctica was organised in November 1963, with due account taken of the experience of the First Air Expedition.

On the night of November 21, 1963, two IL-18 liners took off for Antarctica from Moscow's Sheremetyevo Airport. The planes carried 82 persons, including the head of the Ninth Antarctic Expedition, M. M. Somov. All in all, there were 67 members of the Ninth Expedition.

On December 3, the planes landed on a landing strip near Bunger Oasis, from where the participants of the expedition were flown to Mirny on the expedition's IL-2 and IL-12 aircraft.

Upon landing at Mirny, the ramps were lowered, and one by one the men descended to the ice. The wind was blowing, and all around, as far as the eye could see, lay a smooth plain of snow.

Mirny made a strange impression on the newcomers. They did not see the usual polar winter settlement with houses and streets. "Everything here is hidden under the snow. The only things on the surface are the signal lights at the entrance and the radio aerial poles. To get into any of the houses, you have to squeeze through a narrow trap that is barely visible among the snowdrifts, and climb down several tens of steps by ladder. On the way down you will most certainly be shown at what level the exit was last year and the year before..." [138].

The newly arrived members of the Ninth Expedition soon began work on the programme. Replacement of part of the wintering personnel at the antarctic stations was accom-

* The IQSY Programme had to do only with the study of phenomena directly connected with solar activity. It did not include weather observations on Earth, nor geological, glaciological, oceanographic and biological investigations.

plished for the first time with the help of airplanes, while at Molodyozhnaya, the entire team was exchanged by plane.

On the day that the airplanes reached the antarctic coast, the *Estonia* and the *Ob* sailed from Leningrad, the former carrying the remaining 117 members of the Ninth Expedition and the latter carrying twelve members of the expedition's marine detachment. The *Ob* also took the main load of equipment, supplies and fuel for the expedition. The basic task of this expedition, as mentioned before, was to conduct intensified studies under the IQSY programme.

An important aspect of the expedition's work was its inland tractor and sledge train trip over the route, Vostok—Pole of Inaccessibility—Molodyozhnaya. The train consisted of three tractors, two of which were "Kharkovchanka" snow tractors that towed fully-laden metal sledges. A team of 16 men, headed by A. P. Kapitsa, took part in the trip. The basic scientific staff had come to Antractica on the IL-18 airplanes. The drivers, however, were participants of the Eighth Expedition and had come to Vostok with a transport train from Mirny.

One "Kharkovchanka" snow tractor and the tractor with the geodetic equipment left Vostok Station on January 3, 1964. Heading towards the Pole of Inaccessibility, the staff carried out levelling work (using range-only radar) and conducted gravimetric, glaciological, meteorological and actionometric observations. Every other 100 km along the way, they set up stacks of empty barrels and made astronomical determinations of the co-ordinate points.

The snow tractor, from which seismic soundings were made and magnetic and thermophysical observations were taken, left Vostok Station three days later. It moved independently of the geodetic part of the train, often running far ahead of it to save time for the seismic and thermophysical observations which took longer than the geodetic determinations. At first it was accompanied by two snow tractors, which delivered fuel to a point 200 km away from Vostok Station. Fuel and food were also delivered to the train by airplane.

In general, the weather was favourable for geodetic work, which requires good visibility. The temperature ranged between —24° and —49°C. On January 24, the train reached the highest point of the glacial cover—3,997 m above sea

level. Almost 4,000 m, just like on a high mountain peak! Towards the end of January, the weather got worse; it began to snow, and fog and snow storms made geodetic determinations difficult.

The snow tractor with the seismic equipment reached Pole of Inaccessibility Station on February 1. The station was unsealed, and observations at it began. Because of the bad weather, the geodetic section of the train was held up and arrived at the station only on February 4. On February 6, the train proceeded further, heading for the blank space in the Queen Maud Land region. On February 14, it arrived at a point with co-ordinates of 78°03′S and 19°59′E. Here, at a distance of almost 800 km from the Pole of Inaccessibility, it made a sharp turn towards Molodyozhnaya Station. The weather had spoiled markedly; the temperature dropped to —56°C and the wind increased. There were delays in the air delivery of fuel. In approaching Molodyozhnaya Station, the train had to make detours around areas with crevasses, which were pointed out from the air and also by a special train that was sent from Molodyozhnaya Station to meet the incoming train. Despite the heavy snow storm and white haze, the train succeeded in by-passing the danger zone and arrived safely at the station on March 21, 1964. It had traversed more than 3,300 km in 78 days, covering an average of 42.5 km a day.

The work done en route included seismic soundings to determine the thickness of the glacial cover (at 21 points); gravimetric measurements; levelling of the surface (radio-geodetic as far as the Pole of Inaccessibility, and barometric from there to Molodyozhnaya Station); astronomical determinations at 35 points; magnetic and various glaciological, meteorological and actinometric observations. The programme of observation was carried out in full.

A profile of the glacial cover along the route taken was constructed from the results of the seismic soundings made at reference points and from an analysis of the gravimetric measurements taken at intermediate points. This profile showed that the greater part of the route passed over mountain systems with elevations of the under-ice bed ranging between 400 and 2,000 m. The mountain system twice crossed (once before and once after the turn to Molodyozhnaya Station) was a continuation of the subglacial Gamburtsev Mountains, which becomes exposed in the coastal region on

Cook Peninsula and goes on from there along the ocean bottom in the form of Gunners Shoal. A fuller picture of the surface relief of the glacial cover in the central sector of East Antarctica was obtained on the basis of the profile constructed from data gathered during this trip and from profiles made from data gathered by previous Soviet expeditions. It was now also possible to draw up a map of the bedrock relief of this territory.

When the tractor and sledge train arrived at Molodyozhnaya Station, the *Ob* was there, took the train participants aboard and immediately sailed for Mirny, from where she was to take the participants of the second tractor and sledge train back home to the Soviet Union.

The second train, also formed at Vostok Station, was manned by the transport detachment of the Eighth Expedition that had delivered the loads necessary for the next winter at that station. Taking part in the trip from Vostok Station to Mirny were three Soviet and five French scientists who had come to Mirny on the *Estonia* and flown from there to Vostok. The leader of the train party was P. A. Shumsky. The purpose of the trip was to make a study of the changes in the mass and velocity of glacial cover deformation in the central part of East Antarctica, and also to test a method of electrical logging. From Vostok to Pionerskaya Station, the party made precise measurements of six polygons with the help of tellurometers (range-only radar). Repeat measurements in the future will make it possible to determine the direction and velocity of changes in the glacial cover in the central part of Antarctica. Snow and névé specimens were selected from excavations and barings. The trip lasted 48 days, from February 16, to April 3, 1964.

The day after the train arrived at Mirny, the *Ob* left the shores of Antarctica, taking with it the members of both train trips and the personnel of the Eighth Expedition.

The geologists of the Ninth Expedition continued the study of the western part of Enderby Land by making a geological survey of the Oasis of Tereshkova and a section of the Tala Hills in the vicinity of Molodyozhnaya Station, and also made a reconnaissance examination of the western part of Prince Olav Coast. A marine detachment, consisting of oceanographic, hydrographic and gravimetric teams, worked on the *Ob*.

Aerometeorological and geophysical observations were conducted in the Mirny observatory and at Vostok, Novolazarevskaya and Molodyozhnaya stations.

At the end of November 1964, the *Ob* sailed from Leningrad to Antarctica on her tenth voyage and arrived at Mirny in January 1965. She brought equipment, fuel, foodstuffs and the first contingent of staff, consisting of 18 men. She was followed by the *Estonia* with the main body of personnel—137 persons. The Tenth Expedition conducted stationary observations at the Mirny observatory and at Vostok, Novolazarevskaya and Molodyozhnaya stations. At Vostok Station in the summer, when the temperature remained at a steady —40° to —50°C, a new electric power station was set up and put into operation, and an ionosphere laboratory was fitted out. In the meantime, a small seasonal marine detachment was working on the *Ob*. A year later, the *Ob* made her eleventh voyage to Antarctica, arriving at Mirny at the end of December 1965.

The year 1966 saw the Eleventh Soviet Antarctic Expedition working in Antarctica. As before, scientific observations were conducted at Mirny, at the inland Vostok Station and the coastal Molodyozhnaya and Novolazarevskaya stations. The expedition's seasonal detachments worked throughout the short antarctic summer. They included, for the first time, skin-diving biologists, who discovered over 400 species of organisms at the bottom of the ocean, among which were some that were apparently never before known to science. It was also learned that many organisms, including fish, live not only on the ocean floor, but also on the lower surface of the ice.

In the beginning of January, a tractor and sledge train departed from Mirny carrying fuel and equipment to Vostok.

There was close co-operation between the expedition and the Soviet whaling fleet sailing in the antarctic waters. A unit of the Twelfth Expedition (1967) made a long and difficult inland trip over the route, Molodyozhnaya—Pole of Inaccessibility—the US station, Plateau—Novolazarevskaya.

In 1968, Bellingshausen Station, located on Waterloo (King George) Island off the west coast of the Antarctic Peninsula, began operating. It is the fifth station presently active (the other four are the Mirny observatory and Vostok, Molodyozhnaya and Novolazarevskaya stations). The conditions there are less severe than at the Soviet stations in

East Antarctica. In late February 1968, for example, it was raining on the island and the temperature was +5°C, while at Vostok Station it was —54°C.

The construction crew that built Bellingshausen Station and its winter party came to Waterloo Island on the *Ob*, after which the ship went further round the mainland through the Argentine Admirante Brown Station to Molodyozhnaya Station. This was during the *Ob*'s thirteenth voyage. In the final leg of its journey around Antarctica, the *Ob* came up to the South Orkney Islands, the last land area on the way to Molodyozhnaya Station. In the vicinity of those islands, the *Ob* crossed over an hitherto unknown trough (up to 7,240 m) in the ocean floor.

In December 1969, the *Ob* again sailed to Antarctica bringing the staff of the Fifteenth Soviet Antarctic Expedition to Molodyozhnaya Station. This expedition organised a tractor and slegde train that set up stakes all along the 1,410 km route from Vostok Station to the Mirny observatory. The stakes were set up for the purpose of studying the process of snow accumulation; they also serve as landmarks for subsequent tractor and sledge trips. At Vostok Station a glaciological drilling party, using thermodrilling equipment, bored deep into the ice to extract ice samples for analysis. By August 1970, it had reached a point over 500 m down as it continued to penetrate the continental ice (by the end of 1973 about 1,000 m).

All six of the Soviet stations continued to carry on aerometeorological and geophysical investigations. With the help of the ships (the *Ob* and others) that come to the shores of Antarctica for the summer season, work continues in studying the antarctic waters and conducting geodetic, geological and geographical investigations on the antarctic shores and islands. The Antarctic has already been studied by more than two scores of Soviet expeditions.

CHAPTER 14

A BRIEF REVIEW OF THE RESULTS OF SOVIET STUDIES AND EXPLORATIONS OF THE ANTARCTIC

Only now, in the mid-20th century, can we state that the initial stage in the geographical study of the Earth's surface is near completion. It is marked by the receipt of reliable scientific information about the last, previously unstudied, continent—Antarctica....

"Geography in the System of Earth Sciences", *USSR Academy of Sciences News*, 1963, No. 4.

Soviet researchers have carried out a tremendous number of route and stationary observations in the difficult conditions of bleak Antarctica, on the ice continent itself and in the icy ocean waters around it.

The areas in East Antarctica where the Soviet expeditions worked were once a huge blank space on the map. About 145 years ago, before the First Russian Antarctic Expedition under F. F. Bellingshausen and M. P. Lazarev, the blank space around the South Pole had an area of about 37,000,000 sq km, which is considerably more than the area of Africa (29 million sq km). This huge unexplored part of the world gave rise in the early 19th century to one of the most fantastic theories about our planet: an American scientist by the name of Simms held that the Earth was hollow.

Moreover, Simms said that the inside of the globe was inhabited and that the internal regions had an exit to the surface at the South Pole, where there must be a huge opening. The US Congress debated this question in 1823, and in 1830, an expedition was even organised, but ended in failure.

Gradually, the blank space at the South Pole began to shrink, and in 1956, it was cut up into several sections by air flights. By the end of 1956, that is, shortly before the beginning of the International Geophysical Year, the aggregate area of these sections was about 8 million sq km or more

than half the area of Antarctica (about 14 million sq km). By the end of 1961, the blank space area on the map of Antarctica had shrunk to 3.5 million sq km, which is considerably greater than the area of Kazakhstan, six times the area of the Ukraine, and almost seven times the area of France.

From the diagrammatic map of Antarctica's blank spaces for 1961, it can be seen that the largest blank space lay along the zero meridian and embraced a large part of East Antarctica between the South Pole, the Pole of Inaccessibility and Queen Maud Land, including its southeastern part. As a result of subsequent Soviet expeditions, the blank space area was reduced and, most importantly, cut up into parts. An especially big role in this was played by the Ninth Soviet Antarctic Expedition's Vostok—Pole of Inaccessibility—Molodyozhnaya trek in 1964 (and the Twelfth Expedition's journey in 1967).

Soviet expeditions have studied inland regions that had not only never been explored before, but had also never been seen before, even from an airplane. The coastal zone where Soviet scientists worked had been studied before, but was only poorly and quite inaccurately represented on the map.

Russian contributions to antarctic exploration and, in general, the contributions of Russian and Soviet geography, are reflected in the Russian names on the map of Antarctica: Alexander I Land; Peter I Island; Bellingshausen Sea; Bellingshausen Island (in the South Sandwich Islands); the Bellingshausen island arc (Weddell Sea); Smolensk, Mordvinov and Shishkov islands (in the South Shetland Islands); Shokalsky Strait; Annenkov Island (Scotia Sea); Zavadovsky, Leskov, Vysoky islands (in the South Sandwich Islands), and others. As a result of the work done by Soviet antarctic expeditions, the number of Russian names on the map of Antarctica has increased manifold. Hundreds of new geographical objects were discovered and mapped, such as mountain ranges, peaks, plateaus, valleys, lakes, and glaciers, as well as islands and bays in the sea and ocean waters washing the shores of Antarctica.

The high altitude glacial Sovetskoye Plateau, which appeared on the map in 1959 and stretches from the Pole of Inaccessibility to Komsomolskaya Station in the central part of the antarctic ice sheet, has an area of about 600,000 sq km. Also appearing on the map for the first time that year was the 1,300 kilometre-long International Geophysical Year

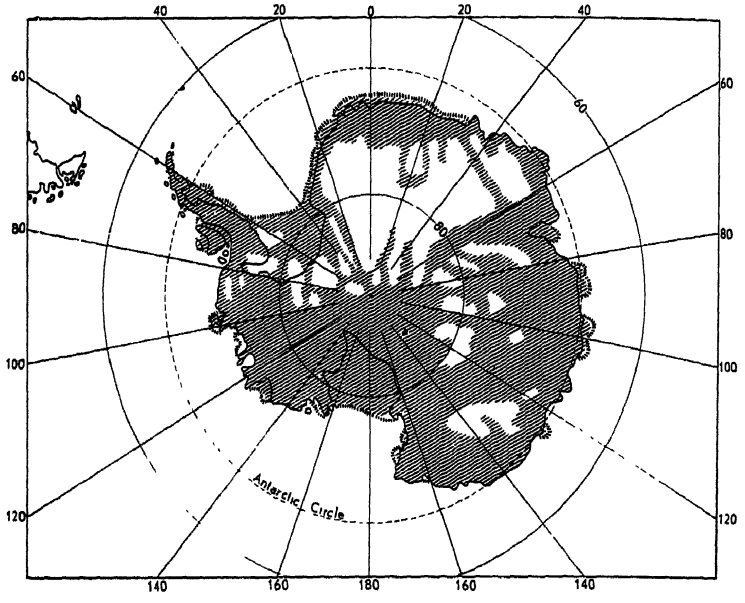


Diagram of the blank spaces on the map of Antarctica in 1961

Valley, which stretches from the western extremity of Sovetskoye Plateau to the Amery Ice Shelf (at the mouth of this valley) and Prydz Bay.

In 1959, after the IGY research work was completed, a new list of geographical names was published, covering the coastal zone of Antractica, between 45° and 166°E or from Prince Olav Land in Enderby Land to Oates Coast. Of the 867 names in the list, 242 were Russian [139].

After that, the Fourth Soviet Antarctic Expedition discovered many new geographical objects in the Queen Maud Land area. A report on Soviet antarctic expeditions from 1956 to 1960 (the First to the Fifth expeditions, inclusive) stated that in the area explored by Soviet expeditions about 250 new geographical names had already been given. This was evidently an underestimation, since there were already almost that many in the 1959 list. Subsequent expeditions made fresh geographical discoveries, and more and more Russian names appeared on the map of East Antarctica.

It would be impossible here to list all of the geographical objects discovered or explored and named by members of

Soviet antarctic expeditions. We shall cite only a few examples taken from the literature and maps.*

Mountain systems, peaks, valleys, hills: Mt. Lodochnikov (west of the Wohlthat Massif in Queen Maud Land); the Russian Mountains (a mountain system between the Wohlthat and Sor Rondane massifs in Queen Maud Land) with Yakovlev, Karpinsky, Zhelannaya and Rusanov peaks; the Mushketov graben (also there); the Morennaya, Radio and Komsomolskaya hills (near Mirny on Pravda Coast); Mt. Borzov (south of the Shackleton Ice Shelf); mounts Obruchev, Berg, Arkhangelsky, Lazarev and Kavraisky, the Vyacheslav Frolov Range (Oates Coast).

Oases: Tereshkova Oasis (in Enderby Land); Obruchev Hills (Oasis), Maly Oasis (in the Bunger Oasis area, south of the Shackleton Ice Shelf).

Glaciers and glacial domes: the Novy, Kroshka, Tsiolkovsky, Leningradsky (Universitetsky), Verblyud domes; Taimyrsky Glacier (at Prydz Bay); the Kuprianov, Kiselev and Angarsky glaciers (east of Mirny on Pravda Coast); the Kuchin Glacier and the MGU and Voyeikov ice shelves (in Wilkes Land); the Krichak, Matusevich, Suvorov and Tomilin glaciers (George V Coast and Oates Coast). The massive but relatively narrow (about 10 km wide) Matusevich Glacier, which flows down along a deep mountain valley, was discovered next to a place where previous maps showed a large bay (about 85 km wide) cutting deep inland—a bay that proved to be non-existent.

Also found to be non-existent were the gigantic, 3,000 metre-high Sjovold volcanoes shown on Norwegian and American maps (including a 1956 American map) in the Amery Ice Shelf sector. Actually, the entire antarctic coastline in that region, as well as in a number of other regions, had been shown inaccurately on the old maps. Such gross errors were corrected by Soviet researchers.

Among the bays, capes, peninsulas and islands discovered by Soviet explorers were the following: Leningradsky Bay, Voronin Bay; capes Ostry, Uraganny, Razlom, Oporny, Murmansky, Sorokin, and Sedov (in the Queen Maud Land sector); Alasheyev, Lena and Khmara bays, Vernadsky and Lamykin peninsulas, Demidov, Galkin, Ilyin islands; and

* Objects of the same type will be named approximately in west to east order.

the Hydrographers Archipelago (in Enderby Land); Nikolayev and Karelin bays; capes Chelyuskintsy and Maximov, and Leskov, Mikhailov and Zavadovsky islands* (in the Western Ice Shelf sector, east of Prydz Bay); Cape Vize, Malygintsy and Milovzorov bays, Novosilsky Island (Shackleton Ice Shelf); Cape Peremenny (Knox Coast); N. Zubov and Miklukho-Maklai bays, capes Smirnov and Popov and Albov Cliffs (in the Wilkes Land sector); Cape Voronin, Slava Bay, Babushkin, Cartographers, Polar Aviation, Znamensky islands, the Sputniks islands, capes Belousov and Sorokin, Kooperatsia and Ob bays (Oates Coast).

Extremely interesting data have been gathered about the bedrock relief of Antarctica. The bedrock relief in the central sector of East Antarctica, including its almost inaccessible inland regions, was first probed by Soviet explorers primarily by means of seismic sounding and gravimetric measurements (seismogravimetric soundings). The map of this relief shows only the most outstanding elements—the large mountain elevations and vast plains—and these have been named after Russian and Soviet scientists.

During the Second Soviet Antarctic Expedition, seismic soundings revealed a horst-like elevation in the bedrock from 200 to 400 km from the coast along the Mirny—Pionerskaya traverse. This elevation was subsequently named the Golitsyn Mountains, in honour of the noted geophysicist B. B. Golitsyn. Bedrock mountains discovered later in the far inland regions of the continent—in the vicinity of Sovetskaya Station and on the way to the Pole of Inaccessibility—were named the Gamburtsev Mountains (also after a noted geophysicist). Their western extension, discovered during the Ninth Expedition, was named the Vernadsky Mountains. A vast bedrock plain, with elevations near sea level, situated east of Pionerskaya and Komsomolskaya stations and extending sublatitudinally, was named Schmidt Valley, in honour of the eminent Soviet scientist, O. Y. Schmidt. And the mountains discovered under the ice in the area of Molodyozhnaya Station, were named the Shchukin Mountains (after the eminent Soviet geographer and long-time professor of Moscow University, I. S. Shchukin).

The volume of work carried out by Soviet expeditions in the sphere of ice-depth determination and geological struc-

* These and some other islands named here are icecaps.

ture and relief determination was indeed great. By 1965, for example, tractor and sledge trains had covered a total working distance of 12,650 km (counting only the distances travelled while actually making seismogravimetric measurements), of which 8,500 km were traversed at an absolute elevation of from 3,000 to 4,000 m, under conditions of difficult movement over powdery snow, extreme cold, low atmospheric pressure, and oxygen deficiency. During these traverses, seismic soundings were made at 200 points and gravimetric measurements at 935. A detailed study of the bedrock relief was made in the vicinity of Mirny.

On the basis of data provided by Soviet and foreign expeditions, a map of the antarctic bedrock relief was drawn up for the *Atlas of Antarctica*. This map, the joint effort of a team of scientists, was later supplemented with new data by A. P. Kapitsa.

Kapitsa, who took part in four antarctic expeditions, summarised the data from his own investigations and all of the Soviet and foreign material on the bedrock relief of Antarctica that had been received by 1965. He came up with an orographic diagram of Antarctica, which, for the eastern part of the continent where Soviet expeditions had worked, looked, in general outline, as follows:

The major plainland elements of the subglacial relief in East Antarctica are the Eastern and Western plains, which occupy a large part of the territory between the Transantarctic Range and the Sredinny Range, and also Schmidt Plain. The absolute elevation of the plains varied between +500 to —500 m. The Sredinny Range consists of the Gamburtsev, Vernadsky and Yamato mountains, which have Gunners Shoal as their submarine extension. The highest point in the Sredinny Range is 3,390 m above sea level.

The next extensive orographic elements are: the Transantarctic Range, part of which, between the Horlick and Teron mountains, also lies hidden beneath a cover of ice; the mountains of Queen Maud Land; and a series of mountain elevations along the coast in the regions of Enderby Land, Wilhelm II Land and Queen Maud Land. The existence of an Eastern Plateau in the centre of the Eastern Plain is surmised [140].

In the course of studying the continent's subglacial relief, certain sections of the bedrock surface were found to be below sea level. This gave rise to speculation that perhaps Antarc-

tica is not a continent, but an archipelago buried under an ice sheet (similar conjectures had been made much earlier, even when nothing at all was known about the subsurface beneath the ice). The conjectures, however, did not have an adequate scientific basis. Geological and geophysical studies have shown that the structure of the Earth's crust in Antractica is typically continental rather than oceanic, and that, especially in the inland sectors, the Earth's crust has sunk under the tremendous weight of the ice sheet. One cubic kilometre of ice weighs about 900 million tons, and there are tens of millions of cubic kilometres of ice in the antarctic ice sheet.* In the central region, the pressure of the ice sheet is 3,000 million tons per square kilometre. This explains why in large areas in the internal part of Antarctica the land surface lies at, or a little below, sea level. But if Antarctica were to lose its ice cover, the Earth's crust there would, according to the principles of isostasy, rise.

Scientists estimate that such a possible isostatic upthrust would average from 500 to 800 m, and they even predict an uneven rising because the level lowland areas should undergo an upthrust of up to 900 m, while the mountains would remain at almost the same height, or, in some cases, even be somewhat depressed.

It is now believed that upon losing its ice cover (deglaciation) and undergoing isostatic upthrust, West Antarctica would indeed become an archipelago, with straits 500 to 800 m deep between the islands. But the vast area of East Antarctica would become a monolithic continent with several deep fjord-like inlets. Nonetheless, Antarctica as a whole should still be classified as a continent, because the antarctic ice is not a seasonal formation and did not originate from sea water. The ice is of continental origin and has existed for centuries (the ice sheet is about one million, or even more, years old); in the inland regions it is motionless and has all the signs and properties of rock. Ice is looked upon as a mineral, and the schistose mass of ice which in the Antarctic is as much as 3,000 to 4,000 m thick, is regarded as a great mass

* Calculations of the volume of antarctic glacial cover according to hypsographic curves show a total volume (excluding the ice shelves) of 23,449,000 cubic kilometres of ice. An approximate determination of the volume made on the basis of a map showing the thickness of the glacial cover gave a figure close to 24,000,000 cubic kilometres.

of rock; therefore, "the continent, composed of ice, is a full-fledged member of the family of continents" [141].

The area of Antarctica is a little under 14 million sq km, or about 12.6 million sq km if the ice shelves are excluded. It is much larger than Australia (7.6 million sq km), but considerably smaller than the other continents closest to it in size (North America—20.4 million sq km, South America—18 million sq km). Estimates of the average height of Antarctica range between 2,160 and 2,330 m. The average height of East Antarctica, where the Soviet expeditions worked, is considerably greater than that of the western part (2,590 and 1,240 m, respectively). Over one-fourth of the area of Antarctica as a whole lies at elevations of 3,000 to 4,000 m, and approximately one-third at 2,000 to 4,000 m. Thus, Antarctica is exceptionally high in comparison with other continents. Consequently, its volume, that is, the rock and ice mass lying above sea level, is greater than that of any other continent except Eurasia, which is, of course, much greater than Antarctica in area.

The results of Soviet geological antarctic explorations have been summarised in a number of monographs, articles and reports. A number of geotectonic diagrams have been worked out for Antarctica (P. S. Voronov, L. V. Klimov, S. D. Ushakov and V. E. Khain). Taking into account the diagrams of his predecessors, especially Klimov's and making use of the latest geological and geophysical data on the Antarctic, A. P. Kapitsa proposed a new diagram, in which West and East Antarctica are fundamentally different in structure. He classifies the Gamburtsev and Vernadsky mountains as Caledonian (lower Paleozoic) folded formations in which there are faults of Cenozoic age. Kapitsa subscribes to the conclusion drawn by Klimov, Ushakov and Khain regarding the relatively young age of the antarctic platform. It is possible to point to only individual Dorithian (Proterozoic) blocks, corresponding to the East and West plains which had later united into a single continent, possibly as a result of Caledonian (lower Paleozoic) orogenesis [142].

Soviet geologists found a variety of minerals in the mountains and oases of Antarctica. It is possible that a few decades from now serious consideration may be given to the possibility of exploiting the mineral riches of Antarctica.

Geological studies have shown that there is a great similarity between the antarctic platform and the continental

platform of South America, Australia, Africa and India. Similarities are observed in the crystalline beds of these platforms, in their sedimentary mantles and even in their fossil floras and faunas. Fossil evidence indicates that, long ago, ancient species of ferns and conifers grew in Antarctica. This fact alone has led geologists to conclude that some 200 to 250 million years ago, the climate there was much warmer and that there was no ice cover on the continent. The geographical position of the world's land mass with respect to the South Pole was evidently different from what it is today. Data from antarctic studies have bolstered the old geological theory that there once existed the continent of Gondwana, which eventually broke apart and drifted in different directions to form Africa, South America, Australia, Antarctica and the Arabian and Hindustan platforms.

Some even more weighty evidence has come in recently. In the Queen Alexandra Range, 400 miles from the South Pole, American explorers found the skull of a reptile whose absolute age is about 200 million years. It is believed to be the skull of a listrosaur, whose remains were found in lower Triassic deposits in Asia and South Africa. The remains of theocodonts (ancestors of dinosaurs and present-day crocodiles) and labyrinthodonts were found in the same stratum where this skull was found. Geologist Laurence Gould, who was the chief scientist with Richard Byrd's 1928 antarctic expedition, believes that this discovery leaves no doubt as to the former existence of the continent of Gondwana [143].

Seismological observations at the Mirny observatory and at Oasis Station registered earthquake epicentres in almost every part of the world. During the first two years of operation, the seismic stations registered about 600 earthquakes, but all of them had epicentres more than 1,000 km away from the shores of Antarctica. The following years also failed to provide any precise data on earthquakes in Antarctica, although from the standpoint of the continent's geological structure their occurrence there is possible. Perhaps the ice lead impedes seismic activity.

The geographers and geologists with the Soviet antarctic expeditions studied the geomorphological features of the rugged mountains of Queen Maud Land, with their sharp peaks and deep valleys and their down-flowing glaciers which come together at the foothills to form a vast ice shelf on the sea coast. They determined the nature of the relief of other

massifs and oases in the coastal zone, studied the various forms of weathering, the effects of glaciation on the bedrock, and the role of glacial activity in the formation of areas of exposed bedrock. A geomorphological map was drawn for the *Atlas of Antarctica*.

The unique oases in the coastal zone attracted a good deal of attention. Soviet scientists became acquainted with an area of exposed bedrock for the first time in Bunger Oasis.

Geographer K. K. Markov, who examined the oasis during the first year of the Soviet Antarctic Expedition, explains the occurrence of this oasis as follows. The basic masses of ice flowing down from the inland regions of the continent bypass the oasis area, and whatever small quantity of ice flows directly onto the oasis is melted by the sun. "The relief of the bedrock, diverting the glacial 'channels' to the sides, and solar heat—these are the factors in the formation of Bunger Oasis" [144].

Geologist M. G. Ravich, who worked in the oasis during the Second Soviet Antarctic Expedition, drew attention to the significance of the solid oasis bedrock, which contains quartz, ferrous and granitic gneiss, and diabase, which resist erosion by wind and frost.

Later, Y. M. Model, a member of the Ninth Antarctic Expedition, and M. G. Grosswald, who explored the glaciers in Franz Josef Land, took a somewhat different point of view regarding the origin of the antarctic oases. They drew attention to the fact that on the outer edges of the continental glaciers there are areas of compression accompanied by crushing and cracking, and areas of heightened ice-flow speed where the channel glaciers form. The deformed and broken-up ice in the compression areas, sometimes forming something in the order of anticlines, acts as a kind of dam for the movement of ice towards the ocean. Behind a system of steep fractures and the zone of crushing or cleavage* in the compression areas on the outer edges of the continental glacier, lies immovable ice. Fast moving channel glaciers flow down around the edges of these sectors, skirting not only the compression areas but also the ice-free surface lying ahead of them, namely, the oases. The channel glaciers move rapidly

* Cleavage is a geological term referring to pseudolamination, where a dense system of parallel cracks resulting from tectonic tensions give the impression of lamination, masking the actual deposition of strata in sedimentary and metamorphic rocks.

and deepen the hollows containing them. Thus the oases are not the result of the unilateral influence of the bedrock on the glacier, but rather the result of prolonged interaction between the glacial cover, with its complicated structure, and the underlying bedrock, which determines the path taken by the ice and at the same time is itself affected by the glacier. Yet it should be stressed that, both in the genesis and in the preservation of the oases in the coastal zones, an exceptionally big role is played by solar energy, the quantity of which in the upper latitudes, as we shall see later, is very great in the summer (the low summer temperatures are caused primarily by the cooling effect of the snow and ice, as well as by the high absolute elevation).

Oases occupy 18 to 20 per cent of the coastal strip of the continent. Their cliffs show the effects of glacial action, and moraine accumulations are found in the depressions between the cliffs. All this indicates that the oases were once ice-laden. Thus, the ice-cover once extended over a greater area and began to diminish in the latest stages of geological history. As a rule, the large oases, such as Bunger, became ice free earlier than the smaller ones, like Obruchev Hills. This is indicated not only by the features of their surface relief, but even by the nature of the spots of lichen covering the cliffs.

Besides Bunger Oasis, Soviet scientists made a detailed and comprehensive investigation of Schirmacher Oasis, where Novolazarevskaya Station was established. The oasis is separated from the ocean by an 80 km wide belt of continental and shelf ice. At first, this gave the impression that the station was set up quite a distance inland. But it was later determined that it was located only several hundred metres from the coastline. A chain of reservoirs extended along the foothills of the steep northern slopes of the hilly oasis elevation. These were found to be nothing other than sea gulfs that are ice-covered the year round. The gulf ice is broken up by tidal cracks stretching along the coast. Variations in water level connected with the tide could be observed.

Soviet scientists studied the antarctic lakes, not only in the oases, but in the mountains where lakes of a new type were found—lakes permanently ice-covered.

Exceptionally interesting were the data obtained regarding the antarctic ice sheet. The thickness of the ice was determined at the same time as the relief features of the surface

beneath the ice were studied. The ice cover has an average thickness of about 2.2 km. with a maximum thickness exceeding 4, perhaps even 4.5, kilometres. Thicknesses of 3,000 to 4,000 m were found in the Eastern Plain, in the part of East Antarctica where Soviet explorations were conducted. At the South Pole, the Soviet measurement of 2,800 m. which differed greatly from British data and a little from American data, was finally, after some controversy in the press, acknowledged as the only authentic determination. The smallest thicknesses of ice cover—800 to 1,000 m—occur in areas of maximum elevation in the inland regions. Antarctica differs in this respect from Greenland, where maximum ice thickness is found in the glacial divide area. In Antarctica, on the other hand, foci of ice diffluence coincide with the regions of bedrock elevation.

Valuable data were obtained on the structure of the ice sheet, on the various ice and snow-and-firn layers in vertical section, and on the dynamics of the antarctic glacier. It was learned that the ice in the central part of the continent is motionless or almost motionless, and is basically very old. Replenishment of the ice reserves due to atmospheric precipitation occurs closer to the periphery of the glacier. The flow of the glacier towards the sea, which takes place with considerable speed in the so-called channel glaciers, also begins at the periphery. These channel glaciers flow towards the sea like rivers with banks made of ice. Since they flow considerably faster than do their banks, they are framed by series of crevasses. The foundations have been laid for the further study of glacier movement and of the on-going changes in the ice cover.

Calculations and various factual data point to the possibility that the bottom ice in the central regions of the continent melts from the heat coming from within the depths of the Earth.

The question of the past and present development of the antarctic ice cover is controversial. Many noted students of the sixth continent, beginning with R. Scott, have supposed that the growth of its ice cover must occur during periods in which there is a reduction of glacier ice in other regions, particularly in Europe, and when the general climate becomes warmer. Any further drop in the temperature in Antarctica would necessarily lead to a reduction of atmospheric precipitation and hence a reduction of glacier feed. The

glacier can advance by virtue of increased feed as the climate gets warmer, while ice wastage would not increase, since in either case it occurs almost exclusively through the breaking off of icebergs. The resultant picture is one in which glaciation in most regions of the world is not simultaneous with glaciation in Antarctica, which is colder than the other regions. P. A. Shumsky, however, believes that Soviet studies of the antarctic ice cover show this to be an erroneous conception. Like all the rest of the Earth's glaciers, the antarctic ice cover expands as the climate becomes colder and shrinks as it gets warmer, although considerably slower than small glaciers. In other words, the warming up of the climate and shrinkage of antarctic glaciers occur simultaneously.

However, K. K. Markov disagrees with Shumsky. He insists that "there is no evidence of synchrony in the characteristic stages of glaciation in Antarctica and Europe (or the United States). Measurement data indicate that in recent years the volume of glaciation has increased in Antarctica, while in other regions of the world it has decreased. Thus the history of antarctic glaciation is profoundly unique in all respects" [145]. Analysing the present trend in antarctic glaciation, V. M. Kotlyakov also leans towards the views of R. Scott, K. K. Markov and others who support the notion that antarctic glaciation increases as the climate becomes warmer. "The basic tendency in the present development of antarctic glaciation is as follows: its mass is increasing, and if present climate conditions persist, the recession and stationary position of the side sectors will be replaced by the advance of the ice cover" [146].

Detailed studies were also made of Antarctica's ice shelves, its snow cover, the nature of the snow surface, direction of the sastrugi on it in relation to the circulation of the atmosphere, and the connection between glacier development and behaviour, on the one hand, and snow accumulation and firnification, on the other. In 1964, the Ninth Expedition's tractor and sledge parties occasionally witnessed the curious phenomenon of so-called firn tremors, when the snow surface would begin to vibrate with a rumbling and cracking sound. Whenever this happened, the snow cover would settle. Such vibrations can spread to a depth of three to four metres and involve an area of several tens of square kilometres. The sudden settling of the upper layers of snow and firn can be caused by a tractor and sledge train moving over the surface.

In fact, equilibrium in the snow mantle may be upset even by a man walking or by a gust of wind.

Science fiction writers sometimes suggest schemes for melting the antarctic ice sheet. If the antarctic glacier ice were to melt, the resulting rise in sea level would submerge about 6 million sq km of land, including thousands of cities and towns. Besides, antarctic ice preserves the contrast that has been established in the Earth's atmosphere between the equatorial and polar regions, which serves as a source of energy for the circulation of air masses. The melting of the antarctic ice, if it were to be accomplished by means of some source of energy, could upset the atmosphere's circulation regimen and lead to undesirable changes in climate in many countries. Leaving science fiction aside, it should be noted, incidentally, that fluctuations in antarctic glaciation indeed affect the level of the World Ocean.

Through the selfless efforts of Soviet researchers, the main features of the weather and climate of East Antarctica have been ascertained.

In the summer, Antarctica receives much more solar heat than the subtropics; this is due to the length of the polar day, the cloudless sky, and the purity and transparency of the atmosphere. But 80 to 90 per cent of the incoming solar radiation is reflected by the snow surface, which absorbs only a small portion of the solar energy. In the winter, however, during the polar night, the ice continent receives virtually no solar energy at all, and undergoes drastic cooling. This explains why in the interior regions, with their high absolute elevations* and rare atmosphere, the climate is so severe, dry and cold. Cyclones, which bring warm air and precipitation, rarely reach the deep interior. The central part of Antarctica is the only region on Earth that receives almost no warmth at all during the polar night. Not only does warmth fail to reach the surface of the ice sheet from the sun or from below, from inside the Earth (because of the massive layer of ice), but almost none at all is brought by air currents from the ocean.

The wintering parties at Vostok, Sovetskaya and Komsomolskaya, located in the central part of Antarctica at an absolute elevation of about 3,500 m, had to work under incon-

* Between Mirny and Pionerskaya, the temperature drops an average of 1.1° C for every 100 m rise in elevation.

ceivably cold conditions. During the polar night the temperature would drop below —80°C! At such temperatures, kerosene turns to jelly; diesel oil becomes such a thick mass that it actually loses its fluidity; and matches have to be warmed up before they can be lit. Metal becomes brittle, and rubber hose and wire insulation burst at the slightest bending. At —85°C you can extinguish a burning torch in a pail of petrol, for at that temperature petrol completely stops vaporising. The extreme cold caused tooth enamel to crack, and there were cases of frost-bitten lungs and corneas.

Absolute minimum temperatures at the Earth's surface were registered at Vostok: —87.4°C (August 25, 1958) and —88.3°C (August 24, 1960). In August 1958, when the temperature at Vostok was —87.4°C, it was —86.8°C at Sovetskaya, a difference of only 0.6°. Sovetskaya was closed down the following year, so there was nothing with which to compare the record low at Vostok (—88.3°C). But while both stations were operating simultaneously, they were always in close competition with respect to low temperatures.

On the basis of temperature measurements in snow wells at a depth of 15 m it was established that temperature minimums of —95° to —100°C could exist on Sovetskaya Plateau in Antarctica.*

Systematic observations continued, and are still going on, at Vostok. The wintering personnel at the station wear special climatic clothing that warms up the air they breathe.

The pole of cold is one of five poles in Antarctica (the five are the geographic, magnetic and geomagnetic poles, the Pole of Inaccessibility and the pole of cold; the latter three were reached and discovered by Soviet explorers). But still another pole is singled out in Antarctica—the pole of wind. Strong winds are almost never observed in the central regions (at Vostok, wind velocities almost always range between 3 and 7 metres per second), but in the coastal zone, winds frequently reach hurricane speeds. The world pole of wind is located in East Antarctica, not within the sector of the Soviet expeditions' basic operations, but further east, in Adélie Land, in the vicinity of the French Dumont d'Urville Station. On February 22, 1951, the average wind velocity there for that day was 45 metres per second, with gusts

* In 1965, the Norwegians recorded a temperature of —94.5° C not far from the South Pole—a world record.

as strong as 90 metres per second! However, while the Dumont d'Urville Station area, located at the mouth of a valley over which drainage winds come rushing out from the interior of the continent, may be considered the world pole of wind, the entire coast from Enderby Land to Adélie Land where the Soviet Mirny, Molodyozhnaya and Oasis stations were set up, should be called the storm coast, for there, winds frequently attain hurricane velocities. Winds exceeding 15 metres per second are customarily considered to be a storm. At Mirny and at the Australian Mawson Station, such winds occur almost daily during the winter months.

Soviet antarctic explorers frequently had occasion to experience a peculiar optical effect that has come to be called "white darkness" or "white haze". When a stream of sunlight, diffused by clouds, hits the surface of the snow, it is subjected to repeated reflection between the snow and the clouds. When the density of the cloud layer and the intensity of illumination come into a certain correlation, the eye perceives no difference in the brightness of the snow surface, the atmosphere and the clouds. All that can be seen is milky white space shining all around, and no objects can be distinguished for orientation. Everything seems to have dissolved in a stream of bright milky light. This phenomenon of "white darkness" is very dangerous for flyers, especially when they have to make a landing. It can also throw a tractor driver off course and bring him to a dangerous precipice without his seeing it. And it is very unpleasant to a man on foot; it gives him the impression that he is walking on an "invisible" surface, and he finds himself tripping and falling in places that are even only slightly uneven.

In both the coastal and interior parts of Antarctica, so-called superior mirages are observed: a distant object is seen on the horizon, reflected upward and inverted. This phenomenon occurs under conditions when the lower air is colder and therefore denser than the air immediately above it.

East Antarctica is divided (V. A. Bugayev, L. D. Dolgushin and others) into three natural, basically climatic, zones: 1. The high antarctic plateau, or central zone, with the severest climate found anywhere on Earth. Atmospheric precipitation occurs there in the form of little columns and plates, which are ice crystals that are called atmospheric ice. They are what make up that powdery snow that for vehicles is just as bad going as drifting desert sand. 2. The antarc-

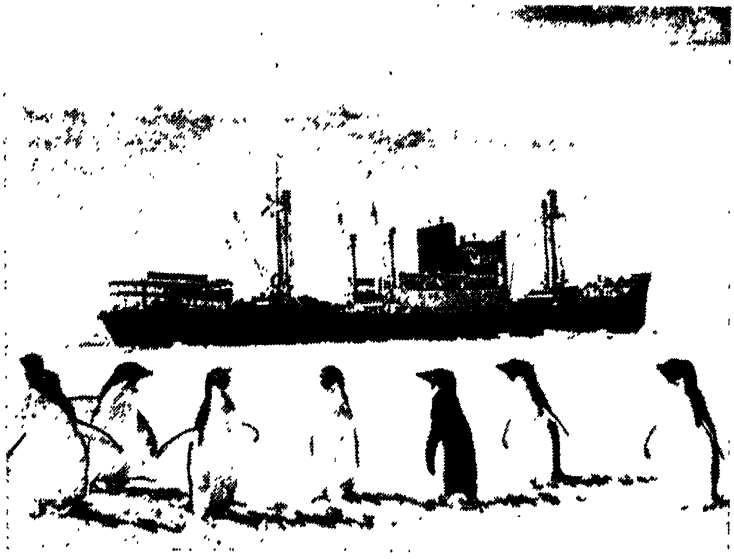
tic escarpment, or the zone of drainage winds, noted for the fierce winds that blow from the interior to the coast. In winter and in summer, this is a region of almost constant snowstorms (25 to 29 days a month in winter, 15 to 20 days a month in summer). 3. The antarctic coast, with relatively calm and warm summers and furious winter hurricanes. Also distinguished is a forth zone, an outer oceanic zone, 20 to 30 km wide, but it is located beyond the borders of the continent. A tremendous amount of snow accumulates here in the winter on the fast ice, because the drainage winds carrying the snow from the coast die down when they reach this zone. All of these zones differ from each other not only in climate, but also in the relief of the snow, its nature, ice cover and in other natural features.

Data from weather and climate observations made by Soviet expeditions, particularly from those conducted at the permanent stations, are important primarily for forecasting the weather in the various regions of Antarctica itself, where there is not only extensive exploration being conducted with the help of airplanes and other forms of transportation, but intensive whaling operations also continue. But these observations also have a wider significance, since Antarctica's cooling influence is spread far to the north by air and ocean currents. Geophysicists studied the Earth's magnetism in East Antarctica, and other aspects of the body of interconnected phenomena, which includes polar aurora, ionosphere processes and cosmic rays.

The organic world in Antarctica is poor, but at the same time, distinctive. Biologists worked in the coastal and interior regions conducting observations of birds and fin-footed animals, studying their life cycles, and gathering material on the embryo development of the emperor penguin. Botanists examined the vegetation and gathered collections of plants. These collections included algae, mosses and lichens. Lichens were found even in the deep interior of the continent on separate nunataks. Two species of flowering plants were found only at the northern extremity of the Antarctic Peninsula.*

Velvety mosses, black and greenish, are found on patches of shallow soil between rocks and in crevices. The lichens, on the other hand, grow right on the rocky surface. Black

* Formerly known as Graham Land.



Penguins on the coast of Antarctica

and grey patches of lichens cover the north side of cliffs where they get plenty of sun and are protected from the wind. Actually, the wind itself is not dangerous for the lichens, but rather the snow and sand that it carries with it. The dark colour of the mosses and lichens is a form of adaptation to the cold climate. They absorb the warmth of the sun rays well and begin to develop early in the warm season. In summer they receive moisture from the melting snow.

The only forms of land animal life living on the continent near the coast are birds and invertebrates; there are no land mammals, fresh water fish or flying insects at all in Antarctica. The life of all antarctic birds is closely associated with the ocean. The wingless fly is the "largest" of the living creatures that can be considered indigenous to the continent. Tiny ticks are known to have been found in the Antarctic Peninsula, and recently, a New Zealand entomologist discovered insects and ticks in the Shackleton Ice Shelf area. Three species of seal are found on the sea ice and in the off-shore waters: the Weddell seal, the crabeater seal and the leopard seal.

In studying the geographical distribution of plants and animals, scientists (M. M. Gollerbach and E. E. Syroyech-

kovsky) distinguished five life zones ranging from the interior to the periphery of the continent: 1) the antarctic ice sheet with its rare instances of exposed bedrock, where vegetation is particularly poor and consists mainly of lichens, and where the only animal life consists of an occasional stray bird; 2) the young antarctic oases, which are usually isolated territorially from the sea, where the sparse vegetation consists of algae, lichens and mosses, and where nesting birds may be found (the south polar skua, the snow petrel); 3) the mature antarctic oases, connected territorially with the sea and its gulfs, but as a rule separated from the open sea by an ice belt (like Bunger Oasis), with typical antarctic plant and animal life, the latter having firm connections with the sea; 4) the coastal island and ice zone, including the pack ice belt and the ice-free off-shore islands, where marine animal life predominates; 5) the sub-antarctic island zone, where there are no direct climatic influences of the continent, where the biology of the land masses is significantly richer and where higher forms of plant life appear.

Soviet researchers also made many important discoveries in the antarctic waters. Previously unknown features of the ocean floor were revealed by means of echo sounding techniques. The most important of these were an under-water rise ending in the Ob and Lena shoals south-east of the Prince Edward Islands, and the Lazarev Trench, which cuts through the shelf of East Antarctica for a distance of about 2,000 miles. This narrow trench lies 50 to 100 km from the coast and runs parallel to the edge of the continent from Davis Sea to Victoria Land. Its maximum depths of about 1,600 and 1,700 m were located near George V Coast and Clarie Coast. The fact that the trench is so near and parallel to the continental coast suggests a connection between its formation and its proximity to the continent and with the latter's development. There have been conjectures regarding the role played by the continent's vertical movements connected with past changes in the ice load. However, some researchers reject the notion that fluctuations in the ice load had any significant relation to the origin of the main sub-latitudinal depressions in the shelf of East Antarctica; they hold that such depressions were formed by older, pre-Quaternary tectonic movements. Others question the very existence of a single deep-lying trench cutting through the shelf parallel to the coast.

Substantial corrections in the submarine structural relief map were made in many sectors of the antarctic continental slope, namely, at Queen Maud Land, Princess Elizabeth Land, Queen Mary Land, Wilkes Land and Victoria Land, as well as in the western half of the Indian Ocean sector through which the ships heading for Mirny coursed. Much important and fundamentally new information on the topography of the ocean floor was obtained. Depth soundings in some of the vast antarctic gulfs were made for the first time.

The *Ob* played a particularly big role in the study of the ocean floor relief in the antarctic zone of the World Ocean. The marine expeditions on the *Ob*'s first voyages and the marine detachments of subsequent expeditions carried out, besides depth measurements, a broad programme of studies of the antarctic coast and off-shore islands, ice shelves, sea ice and ocean water. These studies were of a general geographic, cartographic, oceanological and geophysical character. The geology of the ocean floor was also studied and biological research was conducted. Among the marginal seas washing the shores of Queen Maud Land, Soviet explorers singled out the Sea of Lazarev, and at Enderby Land, the Sea of Cosmonauts and the Sea of Sodruzhestvo.

On the basis of data obtained by both Soviet and foreign researchers, Soviet scientists have compiled surveys of individual antarctic seas and of the entire antarctic zone of the World Ocean. A morphological survey of the marginal seas has been compiled, as well as diagrams of the circulation of water in the upper layers of the World Ocean, general conclusions regarding the ice regime, the distribution and characteristics of the tidal waves, etc.

The coastal zone of Antarctica is the region in which cold, deep waters of the World Ocean are formed. These waters go far to the north, cross the equator and even influence the climate of the northern hemisphere. Soviet oceanographers have made a detailed study of the formation and movement of the waters of the Southern Ocean.

"Southern Ocean"? the reader may ask. "But there is no such ocean on the map, even the latest map!" That is quite true. But nevertheless many scientists consider the antarctic waters of the World Ocean to be so unique and so much alike in terms of the processes taking place in them that they should not be divided up between the Pacific, Indian and Atlantic oceans, but rather regarded as a separate unit—

the Southern Ocean. The term "Southern Ocean" is now frequently encountered in the literature.

Disagreement exists not only as to whether the Southern Ocean should be separated out,* but also as to how, if it is singled out, it should be delimited. Some proponents of distinguishing the Southern Ocean from the others around it consider it to be bounded by the line known as the antarctic convergence (ranging between latitude 50° and 60°S) where warmer tropical waters meet with cold antarctic waters and there is a marked change in the temperature and salinity of the water and in the kinds and numbers of aquatic organisms. Other scientists give the Southern Ocean a much larger area, drawing its outer limits at approximately 40°S, that is, roughly along the parallel of the southern shores of Africa and Australia, where there is also a clear-cut ocean water boundary (the subtropical convergence of ocean currents). Icebergs discharged by antarctic glaciers have been known to reach this line.

A delimitation close to this expanded version is supported by V. G. Kort, E. S. Korotkevich and V. G. Ledenev, all participants in Soviet antractic expeditions. They draw the outer boundary of the Southern Ocean approximately along 40°S, with a significant displacement to the south only from the eastern side of the extremity of South America. Serving as links connecting all the processes taking place in the World Ocean south of this line are a) the belt of westerly winds in the atmosphere, and, b) in the hydrosphere, a circular current of the southern hemisphere, the so-called antarctic circumpolar current (the current of westerly winds). The antarctic circumpolar current serves as the boundary, north of which the waters of the Atlantic, Indian and Pacific oceans form independent systems with dynamic, physical, chemical and biological characteristics that differ from the systems and characteristic processes found south of this current.

Within the boundaries of the antarctic circumpolar current itself and south of it, there is observed a uniformity of the ocean waters surrounding Antarctica in the form of close-

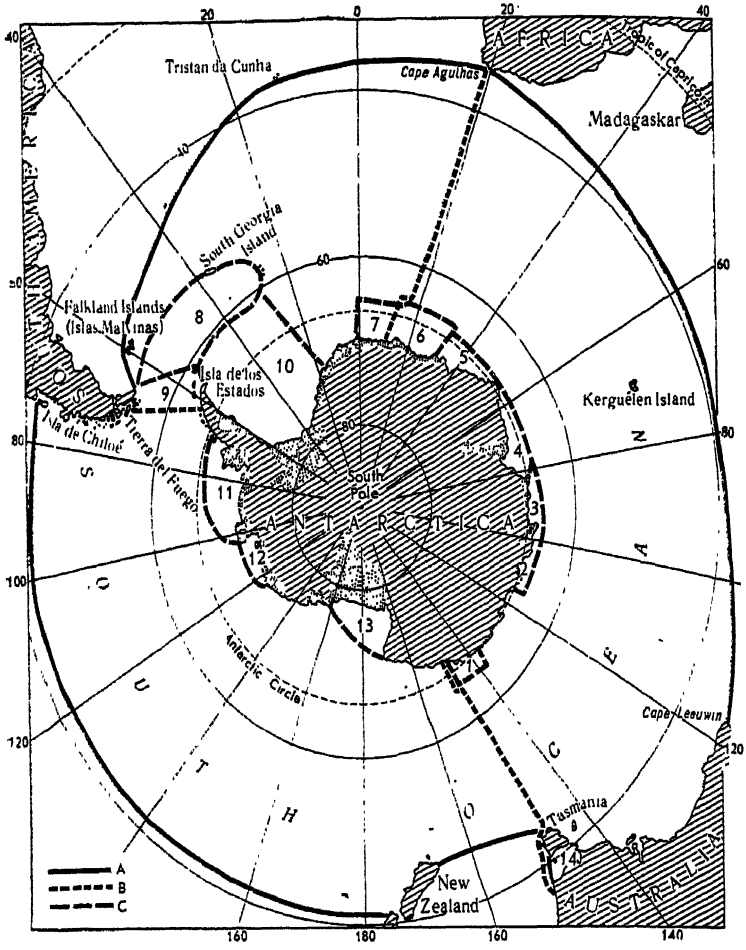
* At the International Hydrographic Conference in Monaco (1952), the point of view of those against separating out the Southern and Arctic oceans prevailed. The World Ocean was divided into three oceans, among which the waters of the Southern Ocean were distributed. It was proposed that the Arctic Ocean be considered an internal sea of the Atlantic Ocean.

ly interconnected circumpolar zones. Thus, south of the northern boundary of the antarctic circumpolar current lies a region of the World Ocean that has, in the opinion of the scientists mentioned above, all the signs of an independent ocean, that is, the Southern Ocean [147]. These scientists raise serious objections to taking the line of the antarctic convergence—which serves as the physiogeographic boundary of Antarctica—as the outer limit of the Southern Ocean. This, they saw, would separate from the Southern Ocean a substantial part of its unifying basis, namely, the antarctic circumpolar current. Moreover, placing the Southern Ocean within the extended boundaries is supported by the zoogeographical chart of the various deep-water regions of the World Ocean, which shows the boundary of the antarctic deep-water region passing just south of 40°S.

If we accept this boundary, then we can say that sea transport routes along the southern coast of Australia, bypassing the southern extremities of Africa and America, lie within the Southern Ocean. The Southern Ocean will remain a major whaling region for a long time to come. The weight of the annual take of valuable whale blubber in the Antarctic exceeds the weight of the fat that could be derived from more than 100 million sheep, and whale blubber is of a higher quality than mutton fat. The whaling industry must be conducted rationally, with strict adherence to existing international agreements.

A physiogeographic breakdown of Antarctica has been made (for the *Atlas of Antarctica*), dividing the continent into a number of circumpolar belts, zones and sub-zones, as well as physiogeographic countries, regions and types of landscape. The data from marine geological and geomorphological research carried on by Soviet expeditions have been summarised (A. V. Zhivago), and on the basis of both Soviet and foreign materials, tectonic and geomorphological maps of the floor of the Southern Ocean have been made.

The extensive research carried out by Soviet scientists in the southern latitudes has made an enormous contribution to the world's treasure house of scientific knowledge. The results of the many investigations have been published in the many volumes containing the materials of expeditions, in more than 50 editions of information bulletins and in hundreds of individual monographs, books and articles. Many general and special maps have been compiled and pub-



The boundaries of the Southern Ocean (A), its sectors (B) and seas (C)
Figures indicate:
1. D' Urville Sea. 2. Mawson Sea. 3. Davis Sea. 4. Sodruzhestvo Sea. 5. Cosmonauts' Sea. 6. Rieser-Larsen Sea. 7. Lazarev Sea. 8. Scotia Sea. 9. Drake Strait. 10. Weddell Sea. 11. Bellingshausen Sea. 12. Amundsen Sea. 13. Ross Sea. 14. Bass Strait

lished. A major geographical work is the *Atlas of Antarctica* [148], which reflects the results of many years of work by Soviet and foreign researchers in Antarctica. It is the world's first comprehensive cartographic work devoted to Antarctica and the surrounding waters. A number of Soviet scientists who played a particularly big role in producing the *Atlas of Antarctica* were awarded the State Prize (1971).

CHAPTER 15

EXPLORATIONS AND THE MOST IMPORTANT GEOGRAPHICAL DISCOVERIES IN THE PACIFIC OCEAN

One of the most important problems facing all Earth sciences is the problem of the Pacific Ocean in all its aspects....

A. N. Zavaritsky

Most of the outstanding geographical discoveries made by Soviet explorers in the non-polar part of the World Ocean were in the expanses of the Pacific.

The exploration of the Pacific is a matter of immense significance. This ocean takes up one-third of the Earth's surface, and its area is greater than that occupied by all of the planet's dry land. It is the greatest ocean on Earth. Yet it is far from being always pacific. In no other ocean are gales and hurricanes as furious as they are on the ocean called the Pacific.

The type of the Earth's crust that is considered characteristic of oceans in general is most widely developed in the Pacific. The formation of the Earth, of its continents and oceans cannot be understood without going into the problem of the origin and history of the Pacific, a problem connected with a whole range of fundamental questions of geology, cosmogony and geophysics. As we see from the words of Academician A. N. Zavaritsky, used in the epigraph to this chapter, comprehensive study of the Pacific is one of the most important tasks facing the Earth sciences. Finally, due to its enormous size and the fact that it extends from the northernmost to the southernmost latitudes, the Pacific provides a particularly clear picture of the pattern of the geographic zonation of the natural features of oceans.

The Pacific and its marginal seas wash the eastern borders of the Soviet Union; hence their all-round exploration and study have been dictated not only by scientific, but also by practical, needs, such as those of fishing and other economic activities, transportation, national defence, etc.

In their all-round study of the Pacific, Soviet scientists are continuing a tradition begun by Russian oceanologists in the last century. The façade of the Institute of Oceanography in Monaco, the oldest of its kind in the world, bears a short list of ships on which the most prominent oceanographic explorations were made. Among them is the name of the Russian corvette *Vityaz*. During the *Vityaz*'s 1886-1889 voyage, which brought fame to the ship and to Russian science, she was commanded by Admiral S. O. Makarov, the founder of Russian oceanography. The route of the famous voyage lay from Valparaiso in South America to Yokohama. Throughout the voyage, Makarov studied the water of the ocean, keeping records of such things as the distribution of its temperature and salinity. The year 1894 saw the publication of Makarov's book *The "Vityaz" and the Pacific Ocean*, which summed up the investigations he had made. The book, which became a classic in the field of oceanography, won the first prize of the Russian Academy of Sciences.

Most of the Soviet explorations and discoveries in the Pacific were also made on the *Vityaz*. But this was another *Vityaz*, a vessel excellently outfitted with modern scientific equipment, the flagship of the Soviet research fleet, named after her predecessor but ranking high above the latter in the scope and results of work accomplished. Indeed, she is the pride of world oceanology.

The studies of the Pacific on the *Vityaz* were begun only after the Second World War.

A good deal, however, was accomplished in this area in the pre-war years. Of great importance were the 1925-1934 expeditions headed by K. M. Deryugin, who also directed the setting up of a scientific station on Cape Basargin near Vladivostok. But seagoing expeditions at that time had technical limitations. They conducted hydrographic exploration mainly off the coastal shoal waters of the Far Eastern seas and the northwestern Pacific. These expeditions laid the basis for making high-quality navigation charts of those areas. But this work was restricted mainly to the continental shelf, with depths of less than 200 m. The bottom relief

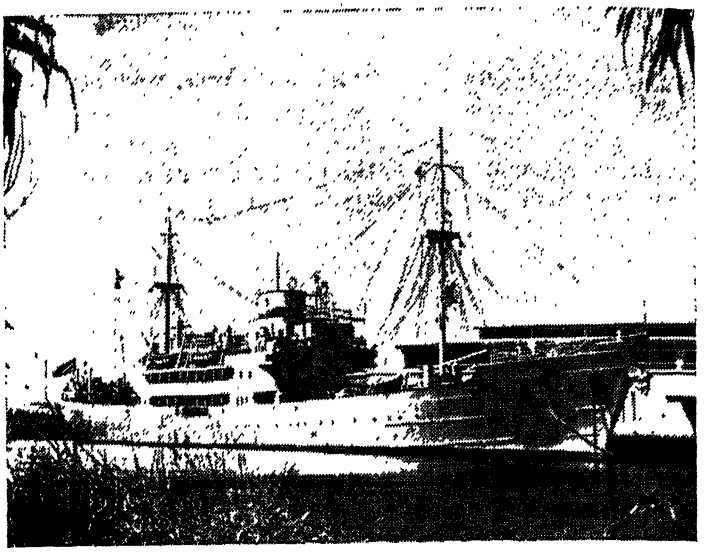
in the deeper areas beyond the continental shelf was little known. Working on the expeditionary vessels *Gagara*, *Lebed*, *Rossiant*, *Krasnoarmeyets*, *Dalnevostochnik*, and others, the expeditions organised by the State Hydrological Institute and the Pacific Institute of Fishing*, gathered valuable information about the depths of the Sea of Japan, the Sea of Okhotsk and the Bering Sea. But that information was relatively limited in scope because the vessels were not equipped with echo-sounding devices.

The lead line sounders of various designs used until recently to measure ocean depths did not afford the possibility of taking enough measurements to get a clear picture of the bottom relief. For each sounding the ship had to stand motionless for a long time. In the chapter on the explorations and discoveries in the Central Arctic we described how difficult it was for Papanin's party to measure ocean depths. It was only natural that when P. P. Shirshov, who had taken part in the heroic drift, became Minister of the Merchant Marine, he devoted much attention to the question of providing research vessels with the latest scientific equipment, for he knew from his own experience how difficult such work was without it. The old sounding techniques persisted for a long time in the Arctic, where even in the post-war years explorers were still making use of the lead line. It was by separate soundings of the bottom that the submarine Lomonosov Ridge was discovered.

Soundings obtained with the lead line did not reflect the numerous irregularities of the ocean floor and gave the wrong impression that it was rather even. The recording echo sounder, on the other hand, records depths automatically in the course of the ship's movement, thus registering all irregularities of the bottom relief.

After the Second World War, Soviet oceanographic expeditions in the Far East were resumed, and by then some expeditionary vessels were already equipped with recording echo sounders. In 1947-1949, with the help of a recording echo sounder, a Kuril-Sakhalin expedition, organised jointly by the Zoological Institute of the USSR Academy of Sciences and the TINRO, gathered valuable data on the bottom relief of the Sea of Japan, the Sea of Okhotsk, and the adjacent

* Later reorganised into the Pacific Institute of Sea Fishing and Oceanography (often referred by the Russian initials TINRO).



The Vityaz

northwestern part of the Pacific. The expedition also conducted an extensive study of the water and the fauna in those areas.

A general study of the water masses of the northern Pacific and their dynamics was made by A. D. Dobrovolsky, who is also credited with a number of other oceanographic studies dealing with that part of the Pacific.

In 1949, the Institute of Oceanology of the USSR Academy of Sciences began extensive studies of the Soviet Far Eastern seas on the research vessel *Vityaz.*

The Soviet Government had given the oceanologists a large refrigerator vessel from the merchant fleet. The ship was then converted into a modern expeditionary vessel, perfectly equipped for protracted and complicated ocean research.

The *Vityaz* is a large ship of 5,546 tons displacement. Its powerful engine can develop a speed of 12-13 knots. The ship is very steady, which makes it possible to do research even in gales. The cabins, which are comfortable and designed for long voyages, can accommodate a crew of about 70, and about the same number of researchers and assistants (60-65 people).

The ship, which has fourteen well-equipped, comfortable and spacious laboratories, is indeed a floating research insti-

tute. It is fitted with the latest devices for hydrological, hydrochemical, meteorological, geological, radiometrical and biological investigations. It also has numerous electrical winches for lowering various instruments into the ocean. In the hold there are drums wound with up to 14 km of thick steel rope.

L. A. Zenkevich

For the greater part of the investigations to be made the engine must be stopped. These stops are called stations. For hours, and sometimes even days, the ship slowly drifts with the current, or lies at anchor while observations are made and hydrological, geological and fauna cores are brought to the surface. Certain kinds of work can be accomplished as the ship moves slowly, while some data are continuously registered even when the ship moves at full speed. For instance, the echo sounders continuously record the depth under the keel by drawing intricate lines on a strip of paper wound on slowly revolving drums.

The *Vityaz* was to be used specifically for the exploration of the Pacific and its marginal seas washing the coast of the Soviet Union—the Sea of Japan, the Sea of Okhotsk and the Bering Sea. In 1949, the Institute of Oceanology, at whose disposal the *Vityaz* had been placed, began a programme of comprehensive explorations of the northwestern Pacific. The first *Vityaz* expedition was headed by L. A. Zenkevich.

The first two years of the programme (1949 and 1950) were spent in sailing the vast expanse of the Far Eastern seas, testing and mastering the *Vityaz*'s complicated and varied equipment.

Later years saw a deeper study of some areas of the Far Eastern seas. The work was conducted by the Institute of

Oceanology of the USSR Academy of Sciences in co-operation with other institutes of the Academy, institutes of the Hydrometeorological Service, the Hydrographic Administration, the Pacific Institute of Sea Fishing and Oceanography, Moscow University, and other scientific institutions. During the first five years the work was directed by L. A. Zenkevich.

From 1949 to 1954, comprehensive oceanographic exploration was conducted in the northwestern Pacific, the Sea of Japan, the Sea of Okhotsk, the Bering Sea, the Kuril Islands area, and the straits in the Kuril Islands arc. Undertaken on the *Vityaz* during that period were four expeditions to the Sea of Okhotsk, two winter expeditions and a number of other voyages to the Sea of Japan, four expeditions to the Bering Sea, one to Tatar Strait, five to the straits of the Kuril Islands arc, and two to the northwestern Pacific. Lines representing the eighteen voyages of the *Vityaz* formed a dense network on the map of the explored area. (See inserted map.) Those expeditions covered a distance more than six times the length of the equator—upward of 130,000 nautical miles; more than 110,000 km of soundings were taken; and 3,219 stations and over 200,000 hydrological, hydrochemical, geological, and biological determinations and observations were made.

In the course of those and other explorations, important geographical discoveries were made that substantially altered the geographical map.

In the Bering Sea, explorers working on the *Vityaz* discovered a large submarine ridge, which divides the deep basin of the sea into two parts. The western part was named the Kamchatsky-Olyutorsky Basin, and the eastern one, the Aleutian Basin. The submarine ridge, about 3,000 m high, was named the Academician Shirshov Ridge. It appears to be continuation of the Hawaiian Ridge, to which it is probably genetically related. The top surface of the ridge lies at a depth of 600 to 700 m.

Many submarine volcanoes were found at the bottom of the Bering Sea, especially in the area of the submarine Patton Rise. Later explorations, made on the *Adler*, supplied new data on the structure of another submarine ridge in the Bering Sea—the Bowers Bank, lying north of the western half of the Aleutian Islands arc, and separated from it by the Bowers Trough.

Many discoveries were made in the Sea of Okhotsk, as well. It was revealed that, besides the previously discovered Kuril Basin, whose exact maximum depth was determined at 3,372 m, there are two large troughs in the shallower northern part of the sea: the Deryugin Trough, with a depth of 1,780 m, and the TINRO Trough, with a depth of 991 m. Also, two large submarine rises were discovered, the USSR Academy of Sciences and the Institute of Oceanology rises. Between them is the Stepan Makarov Trench. West of the USSR Academy of Sciences rise another trench was found, having a depth of over 1,300 m; it was named the Pyotr Schmidt Trench, after a noted student of sea life in the Pacific and Far Eastern waters. South of the TINRO Trough still another trench was found, which was named the Lebed Trench, after a TINRO research vessel. In the vicinity of Jonah Island, a study was made of a broad shoal with an isolated bank, which was named after Kashevarov, an explorer of Far Eastern seas. Two other isolated banks found in the sea were named after hydrographer Staritsky and the research vessel *Lebed* (the Lebed Rise).

Furthermore, a clear picture of the floor of the Sea of Japan was obtained. It contains isolated seamounts apparently of volcanic origin. The ridges in the southern part of the sea are probably related to the main structure of the Japanese islands. In the northern part of the Sea of Japan, an expedition working on the *Vityaz* discovered a submarine rise and a ridge, which were named the Vityaz Rise and the Bogorov Ridge.

The studies carried out on the *Vityaz* indicate that the maximum depth of the Sea of Japan (3,670 m) is located about 90 km south of the Vityaz Rise.

The underwater part of the Kuril-Kamchatka arc has a very complicated relief. These islands are the exposed parts of two submarine ridges, separated by a trough and split into three sections by the Bussol and Krusenstern fractures. This huge mountain mass was found to have on its northwestern slope, facing the Sea of Okhotsk, over thirty-five previously unknown submarine volcanoes. One of the largest was named Vavilov Seamount, after Academician S. I. Vavilov.

The discovery of numerous submarine volcanoes, which substantially supplement the system of above-water volcanoes on the Kuril Islands, is very important for understand-

ing the distribution pattern of the Kuril Islands volcanoes. Some specific features of the arrangement of the above-water volcanoes could not be explained without the data on the distribution of the submarine volcanoes.

The submarine volcanoes are connected with the systems of transverse canyons in the Kuril Islands arc that correspond to the straits between the islands.

The arc's outer ridge, which rises above the surface of the water only in the very south of the arc, was named the Vityaz Ridge.

An expedition on the *Vityaz* discovered three meridional submarine ridges within the limits of the continental slope of the Kamchatka Peninsula. A detailed study was made of the valleys between them, which resemble in size and morphology the famous submarine canyons off the coast of California in the USA.

In the exploration of the Far Eastern seas much attention was paid to the smaller irregularities on the ocean floor, such as the submarine valleys or submerged coastal abrasion terraces discovered, for example, in the Sea of Okhotsk and in the Sea of Japan.

This kind of study was very important for understanding the current processes of relief formation and for making paleogeographical reconstructions in connection with the study of the geological structure of those seas and the history of their development.

The explorations of the Far Eastern seas were continued during the IGY (1957-1958), and later. During the IGY, additional studies were made of the floor relief of the seas and of the distribution of bottom sedimentation, particularly in the Bering Sea. From the bottom of that sea even in the 1949-1954 period of exploration, core samples 33.65 m in length were recovered, whereas previously cores had been only 2 to 3 m long.

In studying the specific structural features of the Earth's crust in the Sea of Japan and the Kuril Basin of the Sea of Okhotsk the seismo-acoustical method was used (in 1957, 1962, 1967, 1970). It was revealed that the sediment layer in that area is no deeper than two kilometres, varying between 1.1 and 2 kilometres. Under it is a basalt layer, whereas some 12 km below the water surface is the so-called Mohorovičić discontinuity, the boundary between the Earth's crust and the mantle.

It turned out, however, that some parts of the Far Eastern seas—the Yamato Rise in the Sea of Japan, the USSR Academy of Sciences Rise at the bottom of the Sea of Okhotsk, the Academician Shirshov Ridge in the Bering Sea—are sunken parts of dry land. They were drowned by the seas during the Neocene Age, at the beginning of the Quaternary Period.

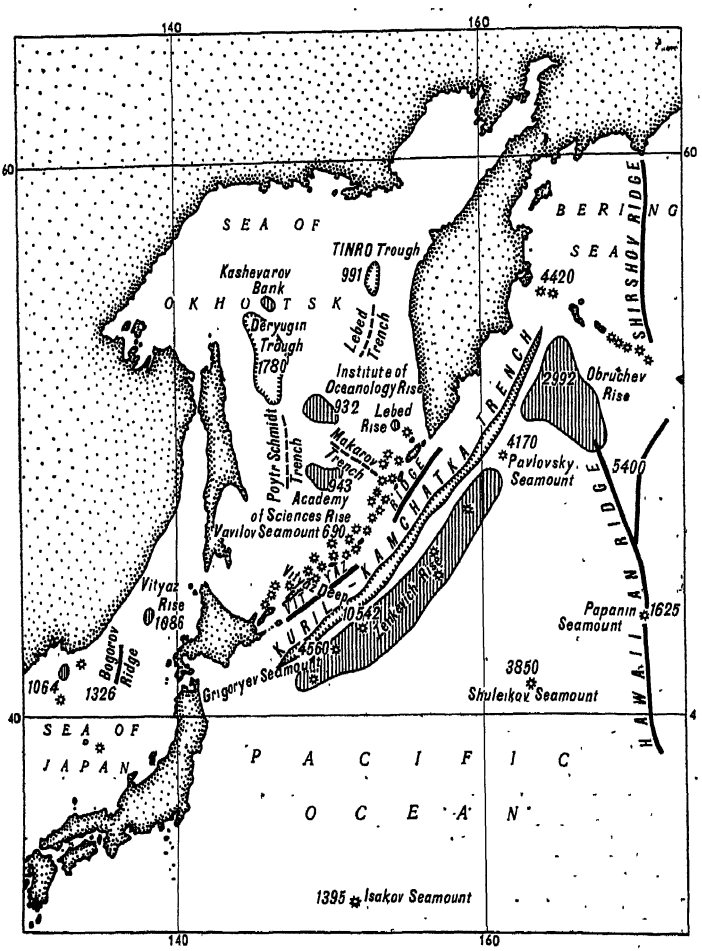
During the IGY and later, Soviet hydrologists conducted extensive studies of the Far Eastern seas. For instance, observations made during the IGY, the 1950-1953 period of research on the *Vityaz* and in 1955 and 1956 on the *Nerpa* clarified the characteristics of water circulation in the Bering Sea. Also, general hydrological descriptions were given of this sea basin, which previously had been very little studied and was the least explored of the Far Eastern seas.

It was observed that the waters of the Bering Sea were considerably warmer. The great similarity in structure between the waters of the Bering Sea and the adjacent part of the Pacific indicated a close connection between this sea and the ocean.

In the Sea of Japan, the distribution of various water masses near the surface was found to be very complicated. A powerful warm current was discovered there, off the southwestern coast of Sakhalin Island. Between the Moneron and Sakhalin, the warm waters of the Tsushima current mix with the cold waters of Aniwa Bay, abundant in biogenic substances. This mixing creates favourable conditions for the development of life and excellent prospects for fishing.

Studies were also made of the hydrochemical and biological characteristics of the Far Eastern seas, and of the chemical properties and mineralogical composition of the bottom sediments. A study was also made of the winter ice limit in the Bering Sea, the Sea of Okhotsk and the Sea of Japan. Studies of the tidal streams in the straits of the Kuril Islands arc were made for the first time, and their regime was found to be very complicated. The data obtained are valuable from the point of view of navigation. The study of the Far Eastern coasts was continued.

Important discoveries were also made in an area of the Pacific near the Kuril Islands. We have already mentioned the discovery of the submarine Vityaz Ridge, a northeastern continuation of the Minor Kuril Ridge whose summits rise above the water surface to form a chain of islands.



Forms of submarine relief discovered by expeditions on the *Vityaz* prior to the International Geophysical Year

South-east of the outer ridge of the Kuril Islands arc and the continental slope of the Kamchatka Peninsula, a huge deep-water trench was discovered, which lies in the north-western Pacific, parallel to the Kuril-Kamchatka arc. A Pacific expedition of the Institute of Oceanology of the USSR Academy of Sciences crossed the trench fifty times on the *Vityaz* in the summer of 1953. The trench was sounded throughout the approximately 14,000 kilometre-long voyage and was found to be one of the deepest ocean trenches in the

world—over 8,000 m deep, with a maximum depth, determined in 1954, of 10,542 m. It is very narrow and has steep slopes (up to 15°). Though the trench is enormously long, its flat bottom has a width of only 9 to 35 km. Within its 6,000 m isobath* the trench has a length of 2,000 km and a width of 20 to 60 km.

A section of the trench had been known before the 1953 explorations on the *Vityaz*, but it was thought to be much shorter, shallower and wider. Its actual maximum depth is more than 2 km greater than had been estimated before.** The depression was then called the Kuril Trench, for it was believed to lie along the Kuril Islands only. Actually, however, it also extends along the coast of the Kamchatka Peninsula and is therefore now called the Kuril-Kamchatka Trench.

The form of the juncture between the northern end of the Kuril-Kamchatka Trench and the Aleutian Trench was revealed. It was found that the northeastern end of the trench penetrates a strait between the Kamchatka Peninsula and the Komandorskiye Islands. The strait has depths of up to 4,420 m. It was proposed that this previously nameless strait be called Kamchatka Strait.

A connection was established between the Kuril and Kamchatka volcanoes, on the one hand, and the neighbouring submarine trench, on the other. The location of these recent volcanoes corresponds precisely to the Kuril-Kamchatka Trench. Mt. Shiveluch, a volcano on the Kamchatka Peninsula, is directly opposite the northern end of the trench. After the 1953 explorations, the geologists who had worked on the *Vityaz* theorised that the Kuril-Kamchatka Trench is an element of a recent geosyncline***, which they named the Kuril-Kamchatka geosyncline.

Seismic activity in the area of the Kuril-Kamchatka Trench provides evidence of crustal movements. There are seismic foci here lying at a depth of up to 60 km. The nearer the foci are to the continent, the greater their depth. In the area of the Kuril Islands arc their depth is moderate, not

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* An isobath is a contour line of equal depth.

** In 1874, an American vessel, the *Tuscarora*, recorded a depth of 8,514 m in the Kuril Trench. This became known as the Tuscarora depth, and the name was sometimes used to denote the entire Kuril Trench.

*** Geosynclines are great downward flexures of the Earth's crust.

exceeding 300 km, whereas further west in the Sea of Okhotsk and the Sea of Japan, there are epicentres of deep-focus earthquakes. The steepness of the trench's slopes and the shallowness of the seismic foci indicate that the recent geosynclinal flexure there is connected with deep lying longitudinal abyssal fractures.

On the basis of explorations carried out in 1953 and later, an excellent geomorphological map of the area of the Kuril-Kamchatka Trench was made.

Expeditions on the *Vityaz* conducted comprehensive studies of the area. No other oceanic depression had ever been as extensively studied as was the Kuril-Kamchatka Trench in the summer of 1953. Studies were conducted throughout the 10-kilometre depth of water. Of particular scientific importance were the results of the study made of deep-sea fauna. Seventeen trawlings were made at depths of over 1,000 m, nine of them at depths of 6,000 to 10,000 m. In the lower depths of the trench many new species, genera, and even families of living organisms were discovered.

On the whole, the data on the Kuril-Kamchatka Trench collected by Soviet scientists are of exceptional scientific and practical value in connection with a number of problems: 1) differences between inner and marginal ocean areas with respect to their bottom relief and crustal structure; 2) the origin of island arcs and the nature of the submarine earthquakes that generate destructive tsunami waves; 3) the distribution and development of life in the ocean.

It was discovered that the long Kuril-Kamchatka Trench joins not only the Aleutian Trench, but also the Japan Trench (which lies east of Honshu Island), the three of them making a huge trough extending along the western margin of the Pacific from the Alaska coast to the Marianas Islands. The greatest depth of the Kuril-Kamchatka Trench approaches the maximum depths of the Marianas, Philippine, Izu-Bonin and other Pacific trenches, which probably indicates that their development is governed by common laws.

The comprehensive programme of oceanological research, which in the open Pacific began in 1953 with a detailed exploration of the Kuril-Kamchatka Trench area (the 14th voyage), was continued in 1954 and 1955. A voyage in 1954, during which a comprehensive oceanological survey was made of the northwestern Pacific, embraced the deep interior

parts of the Pacific Basin. The 1954-1955 programme (the 19th, 20th and 22nd voyages of the *Vityaz*) included exploration of a vast area in the northwestern Pacific, from approximately 52°N to the Tropic of Cancer, during which the ship sailed as far as 2,000 km from the Soviet coast. Below, we review the main results of the work conducted on the *Vityaz* between 1953 and 1955, inclusive.

A study was made of the western part of the Aleutian Trench. Its depth in the vicinity of the Komandorskiye Islands (south of Bering Island) reaches 7,030 m. The slopes of the trench are very steep, in some places nearly vertical; their height reaches 3,000 m. Like the Kuril-Kamchatka Trench, it has a flat bottom. The juncture of the Aleutian and the Kuril-Kamchatka trenches is a level platform slightly higher and wider than the adjoining parts of the trenches.

The juncture between the Kuril-Kamchatka Trench and the Japan Trench, which lies south, is different. There the ocean depths reach 6,700 m, by far exceeding the depths of the neighbouring areas. Thus, the point where the two trenches meet does not break the continuity of great depths; however, the threshold between the two trenches stands out distinctly. In relief the Japan Trench resembles the Kuril-Kamchatka Trench; both have steep slopes and flat bottoms. Explorations showed that the depths in the northern part of the trench do not exceed 7,600 m, whereas older maps showed depths of over 8,000 m.

The *Vityaz* also made a study of the system of trenches lying south of Honshu Island, along Isu, Bonin and Iwo Jima islands. This system, called the Izu-Bonin Trench, differs in morphology from the Japan Trench, once thought to be related to it. In 1955, the maximum sounding of 9,810 m in the Izu-Bonin Trench was obtained.

A characteristic feature of the bottom relief of the Pacific are wide arched uplifts along the submarine trenches in the ocean's margins. One of these is the Zenkevich Rise, discovered by the *Vityaz*, which is actually a chain of rises extending along the Kuril-Kamchatka Trench to form a low, but broad and massive embankment. On its crest a number of conic mountains and steep seamounts rise above a relatively placid relief.

South-east of the Kamchatka Peninsula, the Zenkevich Rise comes right up to another vast rise, the Academician Obruchev Rise, which lies at depths of less than 3,000 m

in the angle formed by the northeastern part of the Kuril-Kamchatka Trench and the western part of the Aleutian Trench.

Joining the Obruchev Rise from the south is a huge submarine ridge, discovered during the 20th voyage of the *Vityaz*. This ridge stretches for hundreds of miles across the entire northern half of the Pacific and rises above the surface only in its southern part, where it forms the Hawaiian Islands. The existence of the Hawaiian Ridge in the central Pacific had been known before, but it was thought to end at approximately 45°N, breaking up into separate seamounts. Explorations on the *Vityaz* showed that in an area where earlier maps indicated depths of more than 6,000 m, there is a ridge rising above the ocean floor to a height of about 4,000 m; a number of summits are at a depth of only 1,200-1,500 m. Fractures break the ridge up into a number of massifs, but the saddles apparently lie at depths no more than 4,000-4,500 m.

The continuation of the Hawaiian Ridge, discovered far to the north near the Obruchev Rise in the vicinity of the Komandorskiye Islands, divides the northern part of the Pacific into two separate basins, the northwestern and northeastern. The ridge is of great hydrological significance as a barrier to deep-water currents. Sometimes it is called the North Hawaiian Ridge; on the latest maps it is designated as the Emperor Seamount Chain.

The discovery of the northern continuation of the Hawaiian Ridge is important above all from the standpoint of geology and geomorphology. It was once thought that the Pacific basin had no central ridge and was therefore essentially different from other ocean basins. Now, the Hawaiian Ridge must be regarded as a "highly important part of a huge mountain system, whose other component parts are the Fanning and Tuamotu ridges and the Southeastern Pacific Rise. This colossal mountain system stretches more or less longitudinally across the entire Pacific Ocean and is comparable in size with the Mid-Atlantic and Mid-Indian ridges" [149].

The explorations made on the *Vityaz* in 1954 and 1955 produced a new conception of the nature of the bottom relief in the northwestern Pacific. Contrary to the old view, this part of the ocean floor was found to be very uneven, and of a rifted and complicated structure. A zone was found where

the bottom relief is exceptionally complicated, something that apparently points to dislocations in the area. This zone, in which seamounts alternate with trenches, lies along the Kuril-Kamchatka arc, at a distance of about 100 miles from the axis of the Kuril-Kamchatka Trench.

An important submarine orographic element of the northwestern basin is the arched uplift which extends in a northeasterly directon from 31°N to about 44°N, and rises 1,500 m above the ocean floor. This uplift was named the Northwestern Rise. Also typical are cone-shaped seamounts. All in all, about 15 major seamounts were discovered there on the *Vityaz*. The cone-shaped seamounts are probably of volcanic origin. On the bottom far out in the open ocean, a considerable number of large fragments of volcanic rock were found, pointing to violent submarine volcanic activity in the area. However, most of the submarine mountains characteristic of this ocean's bottom relief are considered to be ancient volcanoes, formed during the Cretaceous Period.

Explorations on the *Vityaz* not only added geographical elements to the map, but also removed some. This was the case, for instance, with the Ganges Islands in the northwestern Pacific. In the place (at approximately 31°N, 156°E), where older maps showed the Ganges Islands (four islands and some reefs), no islands were found. Moreover, there are no significant submarine rises in the area, let alone seamounts high enough to form islands or even banks.

The studies made disproved the once prevailing view that sediments are spread evenly over the ocean floor, so that the primary bottom relief is either smoothed out or covered by an even coating of sediments. On the contrary, it became evident that in the ocean basins sediments undergo intensive processes of erosion and displacement. These processes lead to the evening out only of depressions in which sediments accumulate. Consequently, in regions far from shores, the ocean floor has intricately fissured as well as level areas.

In 1954, the Institute of Oceanology began a programme of soundings in the Pacific Ocean on the *Vityaz* with the purpose of studying the structure of the Earth's crust. During the IGY, the soundings were continued by the Institute of the Earth Physics of the USSR Academy of Sciences. Interesting data were obtained on the profiles crossing the transition zone between the Asian continent and the Pacific Ocean. It was found that the thickness of the Earth's crust

increases in the area of the Kuril Islands arc and decreases in the Sea of Okhotsk, and especially in the Pacific Ocean. There are also differences in the structure of the Earth's crust. Under the Kuril Islands, the crust consists of a thick sedimentary layer and granite and basalt strata. In the southern part of the Sea of Okhotsk, according to the seismological data obtained, there is no granite stratum. East of the Kuril-Kamchatka Trench, the crust was found to consist of only a basalt stratum covered by a thin layer of sediments. Data derived from gravimetrical observations along the seismic profiles correlate well with the seismological data.

The comprehensive studies of the northwestern Pacific conducted on the *Vityaz* yielded much new information not only about the bottom relief and the structure of the Earth's crust but also about the fauna, the composition of bottom sediments and the hydrology and hydrochemistry of the Pacific. Some of this new information has brought about substantial changes in previous conceptions about that part of the World Ocean.

Hydrological research in the northwestern Pacific was begun by the Institute of Oceanology in 1949, when the first traverse was made over deepwater areas near the Kuril-Kamchatka Trench. In 1951 and 1952, to meet the needs of the fishing industry, a detailed study was made of the waters off the southern coast of the Kamchatka Peninsula (the 6th and 10th voyages of the *Vityaz*). The *Vityaz* carried out extensive studies of the water masses of the Kuril-Kamchatka Trench (1953) and made an oceanological survey of the northwestern Pacific (1954).

Hydrological studies revealed the structure of the water masses in the northwestern Pacific (five types of structure were distinguished), and ascertained the conditions of their transformation and interaction, for example, in the zones where cold and warm currents come together. On all the voyages of the *Vityaz*, meteorological and aerological observations were regularly conducted. Important information was also obtained through hydrochemical studies, which showed, in particular, a slowing down of the processes of organic matter decay in the deeper waters and the absence of stagnant water in the Kuril-Kamchatka Trench.

Very interesting data, some of which were entirely new, were obtained during chemical studies of marine sediments

and of the water saturating them. On the basis of numerous core samples, maps were made of the distribution of sediments in the northwestern Pacific, and light was shed on many problems of sedimentation. Along with the investigations of bottom sediments, the *Vityaz* began large-scale studies of ocean water suspensions. These studies clarified the specific features of the primary stage of sedimentation, made it possible to determine the rate of recent sedimentation and to describe the waters of the Far Eastern seas and the northwestern Pacific in terms of turbidity.

Of particular interest were the results of the biological research done on the *Vityaz*, especially the results of the deepwater fauna studies which the *Vityaz* began in 1949 (in the Kuril-Kamchatka Trench) and continued in 1950-1955, embracing the Far Eastern seas and the adjacent northwestern part of the Pacific. In the course of four voyages in the 1953-1955 period, the *Vityaz* made numerous deepwater trawlings in the northwestern Pacific and explored six trenches, from the Aleutian Trench in the north to the Marianas and Ryukyu trenches in the south. In that period, at depths of more than 6,000 m, the *Vityaz* made twenty-one trawlings and took a large number of bottom specimens. The three deepest trawlings were made in the Kuril-Kamchatka Trench (at depths of 9,000 to 9,050 m and 9,700 to 9,950 m) and in the Izu-Bonin Trench (at depths of 9,715 to 9,735 m). The deepest core sample was taken in the Aleutian Trench (from a depth of 7,286 m).

In the course of these studies, a detailed investigation was made of a previously unknown group of deepwater organisms, the pogonophores. The pogonophores are so unique in structure that zoologists have assigned them to a separate phylum, which stands in close relation to the primitive hemichordates. The main credit for the study of the structure, development and distribution of the pogonophora and for establishing the new phylum belongs to A. V. Ivanov, who worked on the *Vityaz*. Ivanov's book on the pogonophora won the Lenin Prize in 1962.

Besides studying the systematic composition of the fauna at the greatest ocean depths, that is, the ultra-abyssal fauna, the *Vityaz* carried out research into the quantitative distribution of deepwater bottom fauna throughout the northwestern Pacific and its Far Eastern seas. On the basis of the quantitative data obtained on the *Vityaz*, it became possible,

for the first time, to make maps of the quantitative distribution of phytoplankton, zooplankton, and zoobenthos in the World Ocean. During the comprehensive explorations on the *Vityaz*, the laboratories of microbiology, plankton, benthos and ichthyology of the Institute of Oceanology studied the distribution of the plant and animal life in the Kuril-Kamchatka Trench and in the adjacent part of the Pacific to depths of nearly 10,000 m. These studies revealed: 1) the vertical zonation in the distribution of plankton throughout the 10-kilometre depth of water; 2) the lower boundaries in the distribution of the main fauna groups; and 3) the fact that the fauna becomes poorer both qualitatively and quantitatively as depth increases. The ultra-abyssal fauna of the Kuril-Kamchatka Trench was found to be somewhat different from the fauna of the Philippine Trench explored by the Danish ship, the *Galatea*.

During the studies of the deepwater fauna of the Kuril-Kamchatka, Aleutian, Japan, Izu-Bonin, Ryukyu and other trenches, a relationship was found between the biological phenomena, on the one hand, and the geological and geomorphological phenomena—relief, sediment accumulation, distribution of bottom deposits and organic matter—on the other.

The study of deepwater fauna in the Kuril-Kamchatka Trench conducted in 1949 and 1953 (the 2nd and 14th voyages of the *Vityaz*), was a kind of pioneering endeavour. It "upset the once widely held notion that the great ocean depths were lifeless*, and made possible the first diagram of the vertical distribution of the population in a body of water ten kilometres deep" [150]. The work done on the *Vityaz* opened up a new page in the exploration of the abyssal zone of the World Ocean, putting the Soviet Union in the lead in the study of deepsea fauna.

Prior to the work of the *Vityaz*, very little was known about the fish population in the deep waters of the Far Eastern seas and the northwestern part of the Pacific. The work done primarily in 1949, 1953 and 1954 (the 2nd, 14th, and 19th voyages of the *Vityaz*) revealed the existence of about 70 different kinds of deepwater fish in the Far Eastern waters, among which previously unknown species and families were

* Until relatively recently, it was widely believed that life is impossible at great depths where the pressure is 600 to 700 atmospheres.

discovered. In 1951 and 1953-1954, the Institute of Oceanology of the USSR Academy of Sciences, jointly with the Pacific Institute of Ocean Fishing and Oceanography, organised an expedition to study cetaceans in the Kuril Islands area and in the vast expanses of the northwestern part of the Pacific. In addition to studying the cetaceans, the expedition also conducted 900 hydrological stations and made 2,500 specimen catches of zooplankton, cephalopods and fish on which the cetaceans feed.

Between 1949 and 1955, that is, prior to the IGY research period, the *Vityaz* accomplished over 20 separate voyages in the seas of the Far East and the open expanse of the northwestern part of the Pacific. During the IGY (1957-1958), she made several more long voyages in the Pacific Ocean within the northern hemisphere and one voyage (the 26th) that included two meridional traverses extending further south as far as New Zealand.

On the first two voyages of the IGY period (the 24th and 25th voyages), the *Vityaz* investigated the western regions of the Pacific, basically to the north and a little to the south of the equator. Work in these equatorial areas was continued in 1958 during the 27th voyage. During those years a detailed study was made of the Marianas, Yap, Palau, New Britain and Bougainville trenches, and to a lesser degree of detail of the Philippine Trench. Soundings revealed the maximum depth of the Marianas Trench (see below), the Yap Trench (8,527 m, found in 1958), and the New Britian Trench (8,320 m, in 1957). A number of trenches were discovered for the first time: the New Guinea Trench, the Western Melanesia Trench (5,476 m, in 1957) and the Eastern Melanesia, or Vityaz Trench* (6,150 m, in 1958), the latter being located east of the Santa Cruz Islands.

In 1957, during the 25th voyage of the *Vityaz*, a depth sounding of over 11 km (11,304 m, later corrected to 11,022 m) was obtained in the Marianas Trench. Theretofore, the trench was considered to be 10,863 m deep, according to data gathered by a British expedition on the *Challenger*, and that depth was for several years counted as the greatest in the World Ocean. But on January 23, 1960, Jacques Piccard (son of Auguste Piccard, the famous stratonaut and inventor of the bathyscaphe) descended in a bathyscaphe to a depth of

* The second name is now firmly established.

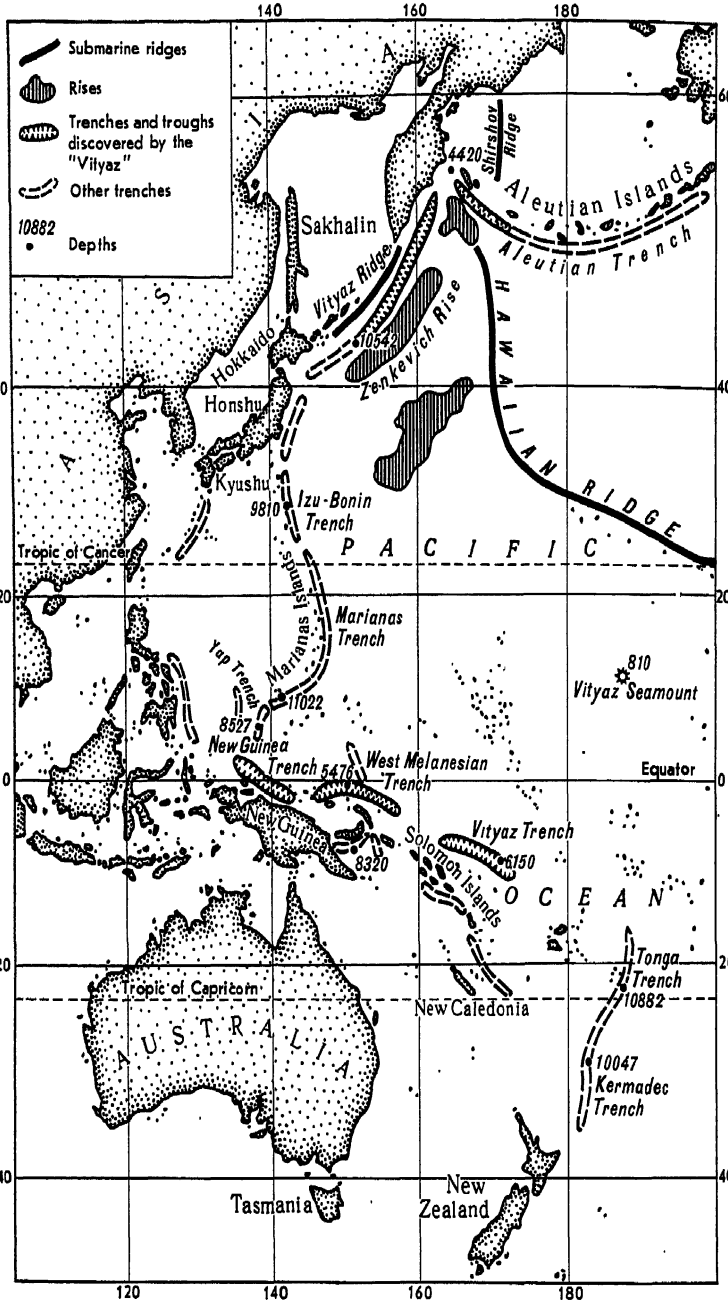


Diagram of the main geographical objects and depths discovered by expeditions on the *Vityaz* in the western half of the Pacific Ocean

11,529 m in the Marianas Trench. Later, it appeared that the Marianas Trench might not have the greatest depth of the Pacific: in 1962, the British Admiralty announced that their hydrographic vessel, the *Cook*, discovered a depth of 11,535 m in the Philippine Trench east of Mindanao Island. It was subsequently determined, however, that Jacques Piccard had actually descended to a depth that was some 600 m less than first reported, and the sounding obtained by the *Cook* was admitted to be erroneous. Thus, the 11,022 m sounding obtained by the *Vityaz* regained its position as the deepest in the Pacific. The *Vityaz* trawled the Marianas Trench at an enormous depth (10,630 to 10,710 m).

In the Caroline Islands area with its depths of 4,000 m, an expedition on the *Vityaz* discovered a seamount, which was named after Miklukho-Maklai. This is a submarine coral atoll with 243 m of water above its crest. The slopes of the seamount are covered with coral material to a depth of 500 m.

During the 25th and 27th voyages of the *Vityaz*, the western marginal seas of the Pacific Ocean were studied. One of the objectives was to gather additional information about the currents of the Solomon Sea (the northern part of the Coral Sea).

The 26th voyage of the *Vityaz*, lasting from November 4, 1957 to February 27, 1958, was especially interesting. Data were gathered along two meridional traverses of the whole central Pacific far to each side of the equator.

Crossing this great expanse twice afforded a clear-cut picture of the natural zones into which the ocean is divided. When the ship moved from the northern into the southern latitudes, she was accompanied by albatrosses. As she proceeded south, the albatrosses diminished and flying fishes appeared—a sign of the approaching tropics. Then the albatrosses disappeared altogether, but the water abounded in squid. The water and air temperature reached 30°C; it became too stuffy to sleep in the cabins, so many slept on deck. Later, far below the equator, albatrosses appeared again—the giant albatrosses of the southern hemisphere. Calm, clear weather alternated with storms, and work would be interrupted for several days at a time. Observations and studies for the IGY programme were conducted at stations every 50 miles along the way. These included studies of current, temperature distribution, salinity and chemical make-up of the water,

ocean floor relief (continuously, by means of recording echo sounders), bottom deposits, and ocean flora and fauna. Work at each station required more than 24 hours.

Just before making a sharp turn to the south, from where a meridional traverse of the central part of the ocean was accomplished, a station was taken above the submarine Hawaiian Ridge. The depth of the ocean there was 2,500 m, whereas the preceeding measurements showed 5,600 m—the usual depth of the ocean floor. At one of the stations around the Hawaiian Islands near the Tropic of Cancer, a large number of very large ossified shaiks' teeth were pulled up from the ocean floor. Trawlings revealed such deposits on more than one occasion. They are the remains of sharks that lived some ten to fifteen million years ago.

Between the Tropic of Cancer and the equator, in an area that was shown on the map to be over 5,600 m deep, a completely unexpected depth of 810 m was sounded. It was the top of a guyot. The ship crisscrossed over it so that a closer examination could be made. The top, about two miles across, turned out to be uneven, with the depths above it ranging between 800 and 900 m. This huge guyot, rising about 4,900 m above the ocean floor, was named after the *Vityaz*.

In the southern hemisphere, the *Vityaz* investigated the Tonga and Kermadec trenches. She approached the Tonga Trench after visiting the Fiji Islands. The trench is over 1,000 miles long, extending in a north-south direction. To the west lies the Tonga island chain, and to the east, it merges with the Southwest Pacific Basin. Down the middle of the trench stretches a narrow, steep-walled trough, in places one, two, or three miles wide. The *Vityaz* followed a zig-zag course along the length of the trench, taking continuous soundings as she went and thus gradually getting a full picture of its contours. "On the fifth day, the sounder registered a depth which, after all the necessary corrections were entered, was recorded as 10,816 m. It was the maximum depth for the Tonga Trench and larger than those found in the trench by the *Capricorn* and *Galatea* (as well as by the *Transpacific—N.G.*) expeditions" [151]. At present, the accepted maximum depth, according to more precise sounding data gathered by the *Vityaz*, stands at 10,882 m. It is the deepest trench in the southern hemisphere.

Letting out 13,000 m of line, the *Vityaz* trawled the trench at a depth of 10,760 m (10,687 m, according to verified data).

"It took five hours to pull the trawl to the surface, and it brought no less than half a ton of bottom sediment. When the sediment was washed it was found to contain a small amount, but quite varied, of ultra-abyssal fauna: holothunia, bivales and gasteropods and various classes of crusteceans. Of all the successful deepsea trawlings described in the literature so far, this is apparently the deepest" [152]. Fauna from a depth of almost 11 kilometres! And only recently it was believed that life at such depths was impossible!

The Kermadec Trench, so named because it lies just east of the Kermadec island arc, was investigated on the eve of 1958. It takes the shape of a narrow trench on the ocean floor. Some 4,000 to 5,000 m deeper than the ocean basin, it is open on both sides, well washed by currents, and shows no signs of water stagnation. The *Vityaz* recorded the trench's maximum depth (10,047 m).

On the way back (along longitude 171°E) after visiting the island of New Caledonia, the *Vityaz* passed over an uncharted submarine ridge north of the Tropic of Capricorn. The echo sounder registered rapidly diminishing depths: 800-200-100 m. Further on, at the beginning of the New Hebrides Trench, depths increased to approximately 7,000 m.

During her 26th voyage, the *Vityaz* came up to a good number of Pacific islands. In Wellington, New Zealand, per arrangement with New Zealand's IGY Committee, the head of the Soviet expedition, V. G. Bogorov, addressed a meeting of the Royal Society of New Zealand, giving a report on the work accomplished. His report furnished a clear picture of the natural division of the Pacific into zones.

The 29th voyage of the *Vityaz*, accomplished under the IGY programme, lasted 160 days, from October 5, 1958 to March 15, 1959. The early part of the voyage was frequently accompanied by bad weather, three times so bad that all observations had to stop. The tasks included an extensive programme of meteorological, climatic, hydrological and biological studies, as well as the study of the geology and geomorphology of the ocean floor. Stations lasting from three to six hours were carried out every 100 to 150 miles, while every 500 to 800 miles much longer stations were made during which detailed investigations were conducted. Altogether, 340 stations were made during the 24,500-mile voyage.

The *Vityaz* sailed through the entire northern half of the Pacific (to the east of the middle, along the parallel, latitude 20°N, and to the west, somewhat north of that parallel) and covered the northeastern part of the ocean in a series of latitudinal and meridional runs. The comprehensive observations, the first work of this kind ever done by Soviet researchers in the northeastern Pacific, added substantially to our knowledge about the characteristics and resources of this area and provided sufficient data to make certain generalisations about the entire northern half of the Pacific.

During the first part of the voyage, the *Vityaz* crossed over the northern extension of the submarine Hawaiian Ridge (between 167° and 170° E) that had been discovered during her 20th voyage. The floor relief to the east of the ridge was found to be very rugged, with spurs of the Hawaiian Ridge and numerous separate seamounts, some of which rose to heights of 1,500 to 2,000 m above the general level of the sea floor. Most of these were as yet uncharted. In approaching the Aleutian Trench a wide bank was discovered that was similar to the submarine banks stretching along the trenches (on the side facing the ocean) in the northwestern Pacific, but differing from them in that it had a more rugged topography.

A bathymetric map of the northeastern Pacific and a map of its floor relief were drawn up on the basis of studies conducted during the voyage, with account taken of data from American expeditions.

Examination of bottom deposits during the 29th voyage was of interest because theretofore such deposits in the northeastern Pacific had been little studied. Manganese concretions were found in large quantity, and iron and manganese were encountered in ore concentrations. Many teeth of ancient sharks were found. All evidence pointed to a very slow rate of sedimentation. The work accomplished included chemical study of bottom sediments, study of the hydrological conditions of the ocean in the autumn-winter season, water circulation, chemical properties of the water, biological studies of zooplankton and phytoplankton, pleiston (fauna inhabiting the top layer of the ocean, literally the surface film of its waters), and pelagic bottom fauna, and deepwater fishes.

In the course of the IGY as a whole, the *Vityaz* investigated many of the Pacific's submarine trenches and discovered

three that had been previously unknown. A more accurate picture was obtained of the depths and relief features of submarine trenches, and the maximum depth mark for the World Ocean was obtained in the Marianas Trench. Trawling at depths of over 6,000 m, in a number of trenches, and at depths of over 10,500 m in the Marianas and Tongo trenches, produced a wide variety of bottom fauna and revealed new depth limits for a number of groups of bottom dwelling animals.

New submarine ridges and other bottom rises were discovered and examined; maps of the floor relief and bottom deposits were drawn up; vast fields of ferromanganese concretions were discovered; light was thrown on the complicated geological and geomorphological processes of ocean floor transformation; a vast amount of data was gathered from meteorological and climatological observations and hydrological, chemical and biological investigations, all making it possible to draw some important conclusions about the nature of the Pacific Ocean and its latitudinal zonation.

Other ships besides the *Vityaz* were involved in Pacific Ocean research during the IGY. The ships *Lomonosov II*, *Zhemchug*, *Val* and others worked in the northwestern Pacific and the Bering Sea, and the *Ob* plied the southern part of the Pacific, primarily in the region now distinguished as the Southern Ocean (see Chapter 14), but also to the north of it.

In the years that followed, the *Vityaz* made several voyages to the Indian Ocean, but between two such voyages (on its 34th voyage) and after them, she continued working in the waters of the Pacific. During the 34th voyage (1961) comprehensive studies were carried out in the tropical zone of the central part of the Pacific. The expedition studied the morphology of the Vityaz Trench (originally called the Eastern Melanesian Trench) discovered in 1958, and found a submarine rise below the equator between Howland and Baker islands on the north-west and Phoenix Island on the south-east. Also discovered were several previously unknown seamounts of volcanic origin, which were apparently islands at one time. It was learned that in the area of the central Pacific investigated by the expedition the rate of bottom sediment accumulation was relatively rapid. Important data on surface and deepwater currents were gathered.

In the northern part of the Pacific, all-round oceanological research was continued on the expeditionary vessel, the *Zhemchug*. It included geomorphological, hydrological and hydrochemical research and the study of the bottom fauna and recent sedimentation. Pacific Ocean research was also conducted on two ships of the Soviet Hydrometeorological Service, the *A. I. Voyeikov* and the *Y. M. Shokalsky*.

For the purpose of conducting magnetic observations in the ocean during the IGY, a small sail and motor schooner, the *Zarya*, was built, the world's one and only non-magnetic ship. She worked in the Atlantic and Indian oceans during the IGY and in the Pacific between 1960 and 1963. During the latter period, three major expeditions were carried out, as a result of which the entire Pacific Ocean was covered in a widely spaced but evenly distributed network of continuous magnetic observations. The observations showed the complexity of the geomagnetic field and the extent and general pattern of magnetic anomaly.

Part of the planned work involved traversing the routes followed in the first half of this century by the *Carnegie* and the *Galileo*. This made it possible to gather information about secular changes in the geomagnetic field. Besides the study of geomagnetism, the *Zarya* also conducted ionospheric observations.

In the summer of 1965, the *Y. M. Shokalsky*, the *Ulyana Gromova* and the *Zhemchug* took part in an international programme for the joint study of the warm Kuroshio current, which flows in a Pacific area of international fishing. In the region where the warm Kuroshio current meets the cold Kuril current, a zone of heightened biological productivity is formed, creating excellent prospects for the fishing industry. The expedition on the three Soviet research vessels experienced the fury of four typhoons. Professor A. M. Muromtsev wrote the following account of one such occurrence:

"Typhoon Shelly caught the expedition in the middle of Kuroshio. All the ships had been warned of its approach and sailed for calm waters. However, we set up a buoy with recording instruments at a depth of five kilometres and stayed to conduct observations during the typhoon. It was the first time in our experience that a buoy withstood such a mighty onslaught of the elements. It gave us interesting data on changes in the vertical structure of the ocean during a hurricane" [153].

In 1966, work under the international programme to study the Kuroshio was conducted on the *Y. M. Shokalsky*, the *Vityaz*, the *Gennady Nevelsky* and the *Orlik*.

At the end of 1965, the *Vityaz* (38th voyage) studied the circulation of the water masses in the northwestern Pacific. In 1966 (39th voyage), attention was focussed on biological investigations in the Kuril-Kamchatka region. These included the study of biological productivity, the quantitative distribution of fauna, the vertical migration of plankton from the surface to the bottom depths, the composition of ultra-abyssal (deeper than 6 km) fauna, and the pattern of change in the latter at progressively greater depths (up to 10 km).

In the preceding decades, the large oceanological expeditions on the *Vityaz* and other research ships were primarily comprehensive. At the present time, however, research methods and the very subject matter in each subdivision of oceanology have become so complex that it is virtually impossible to do a thorough job of research along several lines in the course of a single voyage. Consequently, it is becoming the practice now to concentrate on some one aspect of oceanology during any particular voyage.

For example, the 43rd, 44th (1968-1969), 48th and 49th (1970-1971) voyages of the *Vityaz* were devoted largely to geological studies. During the 43rd voyage, when the task included investigation of deposits of ferromanganese concretions, more than 20 seamounts with heights of over one kilometre were discovered in the central Pacific. One of these, rising to an elevation of 4,400 m above the ocean floor with a minimum depth above its crest of 1,368 m, was named Karpinsky Seamount, in honour of Academician Karpinsky, a famous Russian geologist and former president of the USSR Academy of Sciences. During the 44th voyage, the Vityaz Trench was crossed, and geomorphological and magnetometric studies were conducted in the North Fiji Basin. On the 48th voyage, as on the 43rd, primary attention was devoted to the study of deposits of ferromanganese concretions and the composition and distribution of deepsea sediments. Once again the work done led to substantial corrections in the bathymetric map.

The large research ship, the *Dmitri Mendeleyev*, which began making voyages in the Pacific in 1962, devoted her sixth voyage (1971) to a geographical study of the islands

in the tropical belt of the Pacific. The physiographic zonation on the ocean islands was studied and a great deal of material was gathered on the geomorphology and hydrobiology of atolls and other coral structures in the Pacific. On the way back, an investigation was made of an area north-east of the Marianas Islands, where on the basis of data furnished by Spanish navigators, the Los Jardinos Islands should have been located. A search of this area showed the islands to be nonexistent.

In 1971 samples of ultrabasic rocks from the Upper Mantle were brought on board the *Vityaz* from the northern part of the Tonga Trench.

The *Vityaz*, *Dmitri Mendeleyev* and other Soviet research ships continue their operations in the Pacific Ocean.

The following is a brief summary of the results of Soviet research expeditions in the Pacific, particularly of those conducted on the *Vityaz*. A number of large submarine ridges were discovered and studied, among which were the Vityaz Ridge, the Academician Shirshov Ridge (in the Bering Sea), and the extension of the Hawaiian Ridge (the Northern Hawaiian Ridge). Also discovered and studied were a large number of seamounts, mounts Vityaz, Makarov, Isakov, Shuleikin, Karpinsky, Papanin, Gagarin and Titov, to name a few. Important discoveries were made in the deep-sea trenches, and three trenches were discovered. It was established that the predominating relief forms in the ocean floor are of tectonic and volcanic origin; many submarine volcanoes were discovered both in areas of bottom rises and in the basins, while in the marginal zones of the Pacific, many active submarine volcanoes were found. A large number of long (up to 34 m) cores of bottom sediment were made available for analysis. By means of seismic measurements the thickness of soft sediments was determined (it does not exceed 1,000 m), and its chemical characteristics determined. The Pacific Ocean floor was broken down into mineralogical regions, its geological and geomorphological characteristics fully outlined, and its relief structure summarised in the form of geomorphological diagrams [154].

It was found that inexhaustible reserves of iron and manganese are concentrated on the bottom of the Pacific Ocean in the form of huge tracts of ferromanganese concretions. In the surface layer of the Pacific floor alone such reserves amount to about 90,000 million tons. Similar

concretion concentrations occur in the underlying layer of up to 3 metres thick, so that the total concretion reserves are much greater. Besides being rich in iron (up to 21 per cent) and manganese (up to 40 per cent), the concretions show fairly high concentrations of cobalt, nickel and radioactive elements.

The latest cartographic summaries of our knowledge about the relief and geological structure of the Pacific Ocean floor represent an outstanding Soviet scientific achievement. The first map to the scale of 1 : 10,000,000 of the Pacific Ocean depths, compiled and published under the supervision of G. B. Udintsev, reflects the features of floor relief with greater accuracy and in greater detail than ever before. The tremendous amount of scientific information contained in this map made it possible to use it as a basis—in conjunction with geophysical data, collections of bottom sediment, and underwater photography—to compile for the first time a geomorphological and geotectonic map of the Pacific Ocean to the same scale. These two maps summarise the results of an important stage in the study of the Pacific Ocean.

Much new information has been gathered on the hydrology and hydrochemistry of the Pacific. Extensive investigation has been made of the ocean's hydrological regime, especially in its northern part, and important studies have been carried out of the ocean's water masses and the structure of the waters.

Studies of organic life in the Pacific led to major discoveries, conclusions and generalisations. The upper layers of water were analysed into biogeographic zones. The distribution of plankton was studied not only in the northern part of the ocean, but also in its equatorial waters, and these studies were made in close connection with hydrological data on the water masses and ocean currents. Studies of the deepwater zones, carried out in greatest detail in the northwestern Pacific, led to the discovery of hundreds of new species and a large number of new genera, families and higher categories of fauna. A new chart depicting the vertical zones of ocean fauna distribution was drawn up; it included the ultra-abyssal zone (deeper than 6,000 m)—the zone of abyssal trenches with a highly distinctive animal world. Compared with individual representatives of ancient and primitive deep-sea fauna, the organisms found in the

abyssal trenches turned out to be of relatively recent origin, indicating that the trenches themselves are of relatively recent geological age—approximately three to four million years old.

Needless to say, Soviet expeditions could not, before, during or after their work under the IGY programme, study the great expanses of the Pacific Ocean everywhere with thoroughness. The greatest volume of work was conducted in the northern Pacific and particularly in its marginal northwestern parts, largely because of their proximity to the Soviet Union and to major sea routes and fishing grounds.

CHAPTER 16

EXPLORATIONS AND MAJOR GEOGRAPHICAL DISCOVERIES IN THE INDIAN AND ATLANTIC OCEANS. AN OVERVIEW OF THE STUDIES CONDUCTED IN THE WORLD OCEAN

...When I compare our first expeditions on the "Persei" with the forthcoming voyage on the "Vityaz" in terms of their equipment and tasks and our knowledge and aspirations, I see our maritime science has come a long way.

L. A. Zenkevich

Extensive Soviet explorations in the Indian and Atlantic oceans, not counting the research done in arctic and antarctic waters, began later than in the Pacific, primarily from the time of the International Geophysical Year (more precisely, from the period of preparations for it), which included in its programme the study of the entire World Ocean.

During her first voyage to Antarctica, the *Ob*, after completing a series of studies in the antarctic waters, made an oceanographic traverse across the entire Indian Ocean. The route went from Davis Sea, past Kerguélen Islands to the Gulf of Aden. This oceanographic traverse through the western half of the Indian Ocean (including its southern part, which many geographers and oceanologists consider to be part of the Southern Ocean—see Chapter 14) was about 7,000 miles long and consisted of 41 deep-sea stations. As a result, new data were accumulated regarding the depths, bottom relief, bottom deposits, the waters, atmospheric phenomena and organic life in the western part of the Indian Ocean.

On her 2nd antarctic voyage, the *Ob* crossed the eastern and northern parts of the Indian Ocean. On April 7, 1957, after completing her studies off the antarctic coast and making a series of meridional traverses in the antarctic waters, the *Ob* sailed north from Mirny following a meridional

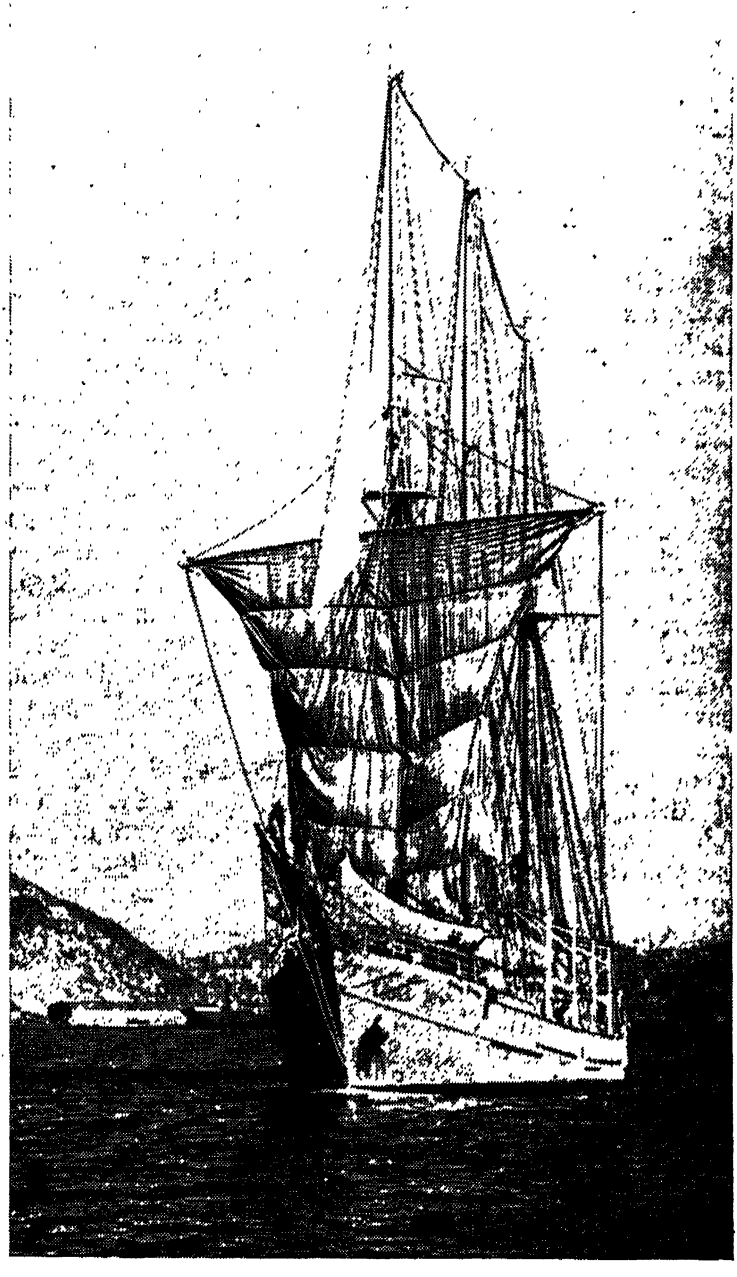
route to the Cocos Islands, where she conducted biological and geological explorations. Then she headed toward the mouth of the Ganges and thus crossed the entire eastern half of the Indian Ocean. The traverse from the shores of Antarctica to the mouth of the Ganges consisted of 49 deep-sea oceanographic stations. Next, she rounded Ceylon from the south and after calling on the port of Colombo proceeded west to the Gulf of Aden, sailed through the Suez Canal and the Mediterranean to the Atlantic Ocean and finally, on June 21, 1957, arrived at Riga. The voyage yielded vast new material from the comprehensive observations conducted along the traverse through the eastern half of the Indian Ocean.

These two large oceanographic traverses, accomplished during the *Ob*'s first antarctic voyages, marked the beginning of extensive Soviet explorations in the Indian Ocean.

During the IGY (1957-1958), and later, in 1959, the Indian Ocean was studied by a geophysical expedition on the non-magnetic schooner, the *Zarya*. Here, as well as in the Atlantic, primary magnetic observations were conducted, the results of which made it possible to resume the long interrupted study of secular changes in the magnetic field in oceans. The observations provided much new material for geomagnetic cartography and revealed the extent of geomagnetic anomaly on the high seas.

In 1957-1958, the *Zarya*'s programme was restricted to continuous magnetic observations and a small complex of hydrometeorological observations (air temperature, atmospheric humidity and pressure, wind, clouds, temperature and colour of surface waters). In 1959, the programme was expanded to include ionospheric and a number of other geophysical observations. The expedition on the *Zarya*, which began in August 1959 over the route, Odessa—Port Said—Aden—Bombay—Colombo—Jakarta—Java Sea—Singapore—Jakarta—Fremantle—Melbourne, conducted observations in the eastern part of the Indian Ocean, thus completing the programme of magnetic and other geophysical observations in that ocean begun in the preceding years. In the beginning of 1960, the expedition headed from Melbourne into the waters of the Pacific Ocean.

An important contribution to our knowledge of the Indian Ocean was made by the voyages of the *Vityaz* that came under an international programme for the study of



The non-magnetic schooner, the *Zarya*

that ocean. The programme, planned for a period of several years (1960-1964), had been worked out in 1959 by a special committee on oceanographic research that had been set up by the International Council of Scientific Unions. The Soviet Union took an active part in carrying out the programme.

The Soviet Union began its part of the work in October 1959. The *Vityaz*, embarking on her 31st voyage, set out from Vladivostok for the Indian Ocean, carrying an expedition of the Institute of Oceanology, headed by V. G. Bogorov. This was the first time the *Vityaz* had ever been to the Indian Ocean. The voyage lasted seven months, ending in late April 1960, when the ship tied up at Odessa after having traversed a total distance of 29,770 miles. The basic work done by the expedition in the Indian Ocean itself was broken down into three stages: investigation of its eastern, central and western parts. The expedition visited Java and also stopped at Christmas Island, where one can see the widespread damage done to the soil and tropical forest by the rapacious phosphate mining practices of an Anglo-Australian-New Zealand company. Other points of contact with continental and island land were: the coast of Western Australia (Fremantle, Perth), Ceylon, India (Cochin, Bombay), the Maldive Islands, Madagascar, Nossi-Be Island and the islet of Nossi-Komba off Madagascar, the Comoro Islands (Mayotte Island), Zanzibar Island off the east coast of Africa, the Seychelles, and the shores of the Gulf of Aden. Detailed studies of off-shore coral reefs were made at many of these points. Basically, however, the *Vityaz* carried on research in the open waters of the Indian Ocean, sailing far from the coastlines into the internal regions of the basin and crossing them in a series of mostly meridional and latitudinal traverses. The last areas to be studied were the Arabian Sea and the Gulf of Aden.

Upon her return to the Soviet Union, the *Vityaz* made a short voyage in the Black Sea (the 32nd voyage), and in the beginning of 1960 again headed for the Indian Ocean. This, her 33rd voyage, lasted six and a half months and ended in April 1961 in Vladivostok. The total distance covered was 31,285 miles. On this voyage the expedition visited Port Said, Aden, Bombay, the Chagos Archipelago, Ceylon (Colombo), Calcutta and Singapore. The Arabian Sea and the ocean waters lying to its south were subjected to a more

detailed study than during the previous voyage. Two enormous meridional traverses were made in the central part of the ocean—from the Indian coast far beyond the Tropic of Capricorn to latitude 40°S, actually right to the outer limits of the Southern Ocean (in its expanded definition). The first meridional traverse went as far as the area just west of Amsterdam and St. Paul islands; the cross-over to the next traverse, which was a little farther east, lay north-west of those islands. A detailed exploration was made of the Bay of Bengal, the Andaman Sea and the area of the Java Trench (its northwestern and central parts).

The tasks of the expedition on the *Vityaz* in the Indian Ocean were complicated and varied. Research was essentially comprehensive in character. The studies covered the relief and structure of the floor; ocean water circulation and especially the deepwater currents; zones of oceanic fronts, that is, zones where water masses with differing properties, such as warm and cold waters, meet; the thermal and CO_2 balance between the sea and the atmosphere; water suspensions (in connection with the formation of sediments); acoustic properties of bottom deposits and accumulations of living organisms; chemical processes in the ocean; the distribution of fishes, plankton and bottom organisms (benthos), with the aim of determining the productivity of various regions of the ocean; the relationships between the physical, chemical and biological characteristics of the ocean and their geographical zonation; the radioactivity of the water and bottom deposits.

The studies of the Indian Ocean on the *Vityaz* came after extensive work in the Pacific, so that by then the research methods were more polished and many new or improved instruments were in use. Geologists took samples of bottom sediment with core samplers 30 m long. As in previous voyages of the *Vityaz*, the ocean floor relief was studied by means of recording echo sounders, while for the study of its structure seismic methods were also used. Sonobuoys were used, making it possible for one ship instead of two to carry out the work and thus speeding up the whole process. Underwater photography was used in studying the ocean floor. Collection of suspensions was carried out by means of powerful separators. Improved techniques for studying deepwater currents were employed, involving the use of deepwater

automatic recording instruments that were attached to the anchor buoy rope at various depths. Currents were also measured while the ship was in motion, by means of an electromagnetic current meter. Use of this instrument required periodic 90° changes in the ship's course. Improved methods and equipment were also used in chemical and radiometric studies, as well as in the study of the ocean's organic world at various depths (trawls and nets of various improved designs were used).

"Sailing on a research ship," writes E. M. Kreps, "above all means work, continuous, unremitting, endless work... the stations take their normal course, day and night, according to plan. And the people stand by their winches and instruments, never quitting them when scorching rays of the equatorial sun beat down on them, or when a tropical downpour lashes the deck, or when the wind, bursting out of the darkness of the night sea, mercilessly whips the plankton nets and, tearing off the crests of waves, douses everyone with salt spray. And in the cabins, the heat and nearly 100% tropical humidity make it so hard to sleep" [155].

In two voyages (the 31st and 33rd) the expeditions on the *Vityaz* conducted more than 500 oceanographic stations, including forty 24-hour stations during which instrument measurements of deepwater currents were made.

The *Vityaz* accomplished more than 57,000 miles of depth sounding out of the 60,000 miles traversed during the two voyages. As a result, an enormous amount of data on the bottom relief was obtained and a number of important discoveries were made.

Located in the northern part of the Indian Ocean are several large and deep basins, separated by huge submarine ridges. Individual ridges and numerous seamounts rise up within the basins themselves. One of these basins is in and to the south of the Arabian Sea. Studies made from the *Vityaz* disclosed that this basin's floor has a very level surface, slightly inclined to the south and composed of marine sediments. Seismic methods were used to determine that the thickness of the bottom deposits decreases (from 2.5 to 0.5 km) as the distance from the Asian coast increases. This is explained by the fact that the clastic material making up the bottom sediments of the Arabian Sea is of land origin. The same picture is observed in the Bay of

Bengal, but there the thickness of the sediments in the north is even greater, up to 3 km, because the bay receives the delta waters of two large rivers, the Ganges and the Brahmaputra.

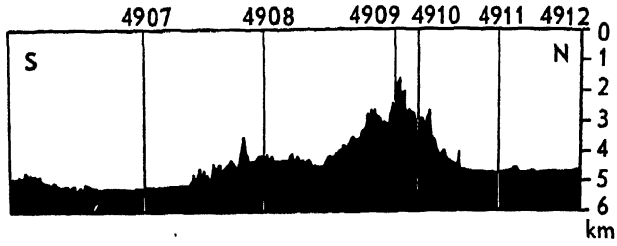
In the northern part of the Arabian Sea the theretofore poorly studied submarine Merrei Ridge was explored. It runs north-east to south-west and serves as a kind of extension of the mountains of Pakistan which come right up to the sea shore in the vicinity of Karachi. The flat tops of individual tablemounts in this ridge lie only 450 m below the surface of the water, while alongside the ridge there is a trench up to 4,230 m deep. It is conjectured that the tops were eroded by wave action near sea level, thus accounting for their flatness, and that subsequently the ridge sank to greater depths.

The Arabian Sea basin is bounded on the south by the Arabian-Indian Ridge. It was found that this ridge is considerably wider than shown on previous maps and that its relief is very complicated. Many previously unknown summits with relative heights of 2 to 2.5 km and outcrops of hard volcanic rock were discovered. At depths of 2,000 to 2,600 m, signs of ripples caused by bottom currents were found in the foraminiferous sand* on the surface of the ridge. The ripples showed up well on photographs taken under water. They were also found in other parts of the ocean bed.

Extending longitudinally through the middle of the Indian Ocean is the Mid-Indian Rise, which continues in the northwest as the Arabian-Indian Ridge. To the east lies a ridge which the latest maps single out as the Maldive Ridge. These longitudinal submarine mountain systems were also explored by the expeditions on the *Vityaz*. The surface of the seamounts in the Arabian-Indian Ridge were found to be exceptionally uneven. A chain of coral islands—the Laccadive, Maldive and Chagos islands—rise from the Maldive Ridge. A steep-walled trench with a flat bottom up to 5,400 m in depth was discovered east of the Chagos Archipelago.

The deepwater Java Trench, stretching for a long distance alongside the Greater and Lesser Sunda Islands, was studied

* A sandy ocean sediment consisting of the shelly remains of foraminifers, small marine rhizopods whose shells are for the most part calcareous.



Echo sounding profile of the bottom in the Afanasy Nikitin Seamount area

Horizontal and vertical scales are at a ratio of 1 : 33. The numbers along the top are the numbers of the oceanographic stations

during both voyages. The structure of the trench was found to be very complex. The steep slopes are complicated by secondary rises, while the bottom is usually flat. Seismic soundings revealed that the layer of bottom sediments is 2 km thick, becoming markedly thinner towards the island side and especially so towards the ocean side. On the outer side of the trench a chain of large bottom rises, crowned with numerous underwater volcanoes, was found to stretch along the length of the trench. Seamounts were discovered between Christmas Island and the Cocos Islands. South-west of Christmas Island discovery was made of a seamount whose crest lies 1,433 m below the surface. It was later named the Shcherbakov Seamount (in honour of Academician D. I. Shcherbakov).

Some 550 miles south-south-west of the island of Ceylon, in an area where the depth of the ocean bed exceeds 4,500 m, discovery was made of a ridge topped with underwater volcanoes. One of the seamounts in this chain, located at 3°S, 83°E, and studied in detail, was named after Afanasy Nikitin, who sailed the Indian Ocean (in the Arabian Sea) in the 15th century. The crest of the seamount is at a depth of 1,549 m.

Another of the seamounts discovered lies in the western part of the Indian Ocean, east of the northern tip of Madagascar in the Mascarene Basin, at 13°55′S, 53°38′E. The minimum depth above this seamount, which was named after Academician I. P. Bardin, chairman of the Soviet Committee on IGY, is 1,510 m. Ir rises to a height of 3 km above the ocean floor.

The bottom relief in the area between Madagascar and the Seychelles was found to have rugged topography. The complexity of its structure in the northwestern part of the Indian Ocean is connected with large fracture zones and differentiated movements of large areas of the Earth's crust along these fractures. The Seychelles are granitic islands, that is, composed of rocks that are characteristic of continents and do not occur in ocean basins. The islands are thought to be remnants of ancient Lemuria, a continent alleged to have occupied a large area of the western part of the Indian Ocean. Further east, as in the basins of the Pacific and Atlantic oceans, the bottom deposits are everywhere underlain by basalts, outcroppings of which are exposed on many bottom projections. Seismic soundings showed that in moving away from the African coast the thickness of the sediment layer gradually decreases; in the central part of the ocean it is no more than 300 m

The bottom relief in the central part of the Indian Ocean was found to be hilly and in places mountainous; in many places there is no sediment layer and bedrock is exposed. This kind of complicated bottom relief with numerous patches of exposed bedrock was also noted in area further south, between 7° and 35°S. In that part of the ocean the rate of sedimentation is very low, the bottom sediments are only a few hundred metres thick, and solid bedrock is exposed on numerous seamounts and hills. Thus, the sediment bottom cover is frequently interrupted not only on submarine ridges but in ocean basins with depths of 4,500 to 5,000 m. It was determined by seismo-acoustical methods that the thickness of the Earth's crust in this part of the ocean is 7.5 ± 1.5 kilometres.

Just as in the Pacific Ocean, found on the bottom of the Indian Ocean were ferromanganese concretions, shark's teeth (recent and ancient, pre-Quaternary) and horny mandibles ("beaks") of squids.

The *Vityaz* expeditions studied the regime, dynamics and properties (salinity, density, etc.) of the waters of the Indian Ocean; the zone dividing the water masses of the northern and southern parts of the ocean (this zone lies at approximately 10-12°S) and the water exchange between them on the west in the Madagascar area; and the influence of neighbouring oceans and seas (the Red Sea and others) on the formation of the water masses of the Indian Ocean.

Special attention was devoted to the study of deepwater and surface currents. A diagram was made of the surface currents of the Indian Ocean on the basis of observations made in the winter of 1959-1960, and further study were made of the movement of surface waters in the western part of the ocean around Madagascar, the Comoro Islands and the east coast of Africa, north of Madagascar. New data were obtained on the structure of trade wind currents and countercurrents, and a new conception of the characteristic of the southern trade wind current was formed.

New to science was the information obtained about the movement of waters in the deeper layers of the ocean. It was the study of deepwater currents that made it possible to ascertain what processes take place deep in the zone dividing the water masses of the northern and southern parts of the ocean, and to observe the transfer of the so-called antarctic intermediate waters that form below 40°S and which, deep down in the eastern part of the ocean, move north with a velocity of 4 to 11 cm per second. The antarctic intermediate waters come together with the Arabian waters—which differ from them in a number of properties, particularly in temperature and salt composition—in the dividing zone at depth within the top two kilometres. Deep waters rise towards the surface in this zone. But at depths of over two or three kilometres, the cold antarctic water masses that were formed south of 50°S penetrate far to the north, even into areas of the Arabian Sea and the Bay of Bengal. Consequently, the bottom waters everywhere are cold (1-2°C). Cold temperatures are also characteristic of the bottom sediments.

Hydrologists and hydrochemists in the *Vityaz* expeditions worked on the problem of what causes the oxygen deficiency in the Arabian Sea. In the deep waters of this sea and in the Bay of Bengal they discovered the presence of hydrogen sulphide, which, like insufficient oxygen, impedes the development of life in deep waters.

Thus, the expeditions ascertained the basic types of water masses in the Indian Ocean, their properties and the characteristics of their displacement. The biologists studied the ocean's plankton, obtained interesting data on the distribution of fish, and identified new species of bottom dwelling organisms. Among the bottom organisms found in the Java Trench were representatives of a number of large

taxonomic groups never before encountered. Some of the species were endemic, while others were identical or closely related to species found in the Pacific Ocean trenches, particularly in the Philippine Trench.

The 35th voyage of the *Vityaz* was also devoted to the study of the Indian Ocean. On this voyage, which lasted 153 days, the *Vityaz* sailed from Vladivostok in June 1962, and returned there in November 1962. Her ports of call were Singapore, Jakarta, Fremantle and Madras, and on the return trip, Singapore again. The distance covered was 20,800 miles, 19,100 miles of which were with continuous echo soundings. The total number of oceanographic stations was 137. The studies embraced the eastern half of the Indian Ocean to approximately 35°S, including the Bay of Bengal in the north, and also a middle meridional strip (south of India and Ceylon) to approximately 12°S. Weather conditions during the voyage were difficult; strong winds, a choppy sea and, in the equatorial zone, fast currents complicated the research process.

Continuous echo sounding produced a vast amount of new data on the contours and details of the relief of the large basins and submarine ridges in the eastern part of the Indian Ocean. Previously uncharted seamounts and trenches were discovered.

The expedition confirmed the fact that the latitudinal West Australian Ridge is isolated from the continental slope. A deepwater trench was traced alongside the southern slope of this ridge. The trench had been crossed during the *Ob*'s second antarctic voyage, but not described. Its maximum depth was found to be 5,761 m. It was named the Ob Trench. Discovered in this area were several other deep and narrow trenches (this is apparently a fracture zone), as well as mountain massifs and high seamounts. A number of seamounts were discovered in the tropical zone, in the middle meridional strip, and in the eastern half of the ocean. The Chagos Trench, which had been discovered during the 33rd voyage, was further studied, and a depth of 5,408 m was found in it.

On the basis of studies made during the three voyages of the *Vityaz* and materials from foreign expeditions it was established that the eastern half of the Indian Ocean contains a huge longitudinal ridge stretching for a distance of over 2,600 miles, from the southeastern part of the Bay

of Bengal to 32°-34°S. A German scientist had previously conjectured that such a ridge existed, but now the fact of its existence was proved conclusively. This required a re-examination of the question of basins in the central and southeastern parts of the Indian Ocean. The enormous Indian-Australian Basin, which according to earlier conceptions occupied the entire area, had to be divided into two independent basins. The one on the north-west was named the Central Basin, and the one on the south-east, the West Australian Basin. The 2,600-mile ridge between them, which has been named the Eastern Indian Ridge, apparently has a substantial influence on the deepwater circulation in these basins.

As a result of studies conducted it was possible to establish the contours of the accumulation plains of the ocean bed and of bottom areas with broken relief. Extensive materials were collected on the composition and distribution of bottom sediments. Confirmation was made of an exceptionally wide distribution of ferromanganese concretions in the deep basins in places where the bottom has a rugged topography. As in the Pacific Ocean, these concretions are hign in nickel, cobalt, copper, lead and a number of other elements. Studies using seismic methods produced new information about the structure and thickness of bottom sediments.

The expedition's programme laid particular emphasis on hydrological research. It will be recalled that the two previous voyages of the *Vityaz* in the Indian Ocean (the 31st and 33rd voyages) took place in the winter season of the northern hemisphere, while the 35th voyage was carried out during the summer monsoon season. It was a time of year in which studies in the tropical zone of the Indian Ocean had almost never been conducted before because of the difficult weather conditions. This was the first time that observations of the currents in the northern part of the Indian Ocean, using instrument measurements at buoy stations, had ever been conducted during a summer monsoon. Constituting the basis for studying the hydrological conditions in this part of the ocean during the summer, the data obtained are of great scientific value and are important to navigation.

A great deal of material was gathered on the hydrochemistry of the northeastern part of the Indian Ocean during the

summer monsoon season, and the distribution pattern of the general biomass of plankton during this period was determined (it was found to be significantly greater than in the winter season). Ichthyological studies also yielded valuable results. Hydrometeorological, aerological and synoptic research was carried on throughout the voyage.

In the autumn and winter of 1964-1965, the *Vityaz* returned to the Indian Ocean to continue work under the international research programme. The planned tasks during this five-month voyage included, among other things, extensive geological and geophysical studies. A most interesting result of this expedition was the discovery of outcroppings, right to the surface of the ocean bottom, of abyssal rock that make up the substance of the upper mantle*.

Working simultaneously with the *Vityaz* in the Indian Ocean between 1959 and 1961 were the *A. I. Voyeikov* and *Y. M. Shokalsky*, both of which conducted hydrometeorological, aerological and synoptic studies under a programme of the Hydrometeorological Service. The fourth voyage of the *Y. M. Shokalsky* (1961) took place in the Tropic of Capricorn zone of the Indian Ocean.

From October 1961 through February 1962, the first expedition of the Azov and Black Sea Institute of Deep-sea Fishing and Oceanography worked in the northwestern part of the Indian Ocean exploring the ocean's fishing resources. From July through November 1962, the same institute's second expedition made a more thorough study of areas recommended by its predecessor. Later, other work in the Indian Ocean was done on a large new expeditionary ship of the USSR Academy of Sciences, the *Academician Kurchatov*. The *Vityaz* also continued research in the Indian Ocean. At the beginning of 1976, it served as the base for a geological study of the East-Indies submarine ridge. That was this veteran Soviet research ship's 58th sailing.

What, in brief, have been the overall results of Soviet studies in the Indian Ocean?

It was not so long ago that R. Revell, an eminent scientist and director of a large American oceanographic institute remarked that less is known about the bottom of

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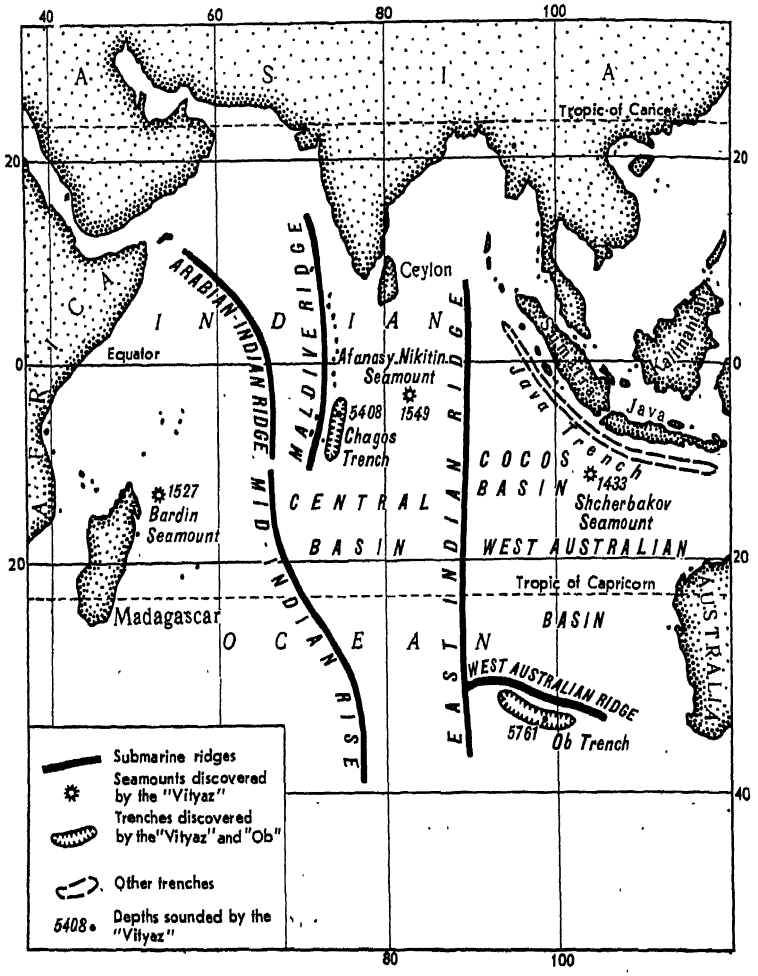
* That is, of the layer lying directly under the basaltic layer of the Earth's crust.



Map showing some of the relief features of the Indian Ocean floor studied and discovered during work on the international research programme in which Soviet oceanologists took part, and features discovered directly by Soviet oceanological expeditions

the Indian Ocean than about the surface of the moon [156]. This idea was repeated later by many oceanologists. Recent efforts, including the Soviet studies carried out primarily under the international programme of research in the Indian Ocean, have resulted in much more accurate and, indeed, an entirely new, conception of the bottom relief of this ocean.

Drawing on the materials of Soviet expeditions on the *Ob* and the *Vityaz* and using the latest data gathered by other countries, Soviet scientists have compiled bathymetric maps reflecting the new conceptions of bottom relief structure for almost the entire Indian Ocean (excluding its southern part, which many regard as belonging to the Southern Ocean), and giving a particularly detailed picture of its northwestern part. In addition, compiling a cartographic summary of all available material was a significant achievement in itself.

Many Russian names appear on the new map of the Indian Ocean [157]. Such names as the Afanasy Nikitin Seamount, the Bardin Seamount, the Shcherbakov Seamount and the Ob Trench all speak of the role Soviet science has played in the study of the ocean depths and the structure of the bottom surface. The Chagos Trench was also discovered by Soviet researchers. The differentiation of such large bottom features of the Indian Ocean as the East Indian Ridge, the Central Basin and the West Australian Basin was also, as we have seen, largely the result of Soviet explorations, and the names now used were suggested by the scientists working on the *Vityaz*.

Soviet scientists succeeded in determining the pattern of bottom sediment distribution, the horizontal and vertical zonation of sediments, the uneven and intermittent nature of their accumulation, the composition of suspended matter in the waters of the ocean, and the distribution of ferromanganese concretions. Using seismic methods they determined the thickness of the sediment cover and the structure of the Earth's crust. The hydrologists revealed important features of the dynamics of the ocean's waters and the patterns of its currents. The biologists discovered new organisms, established the fact of zonation and other features in the distribution of plankton, gathered a vast amount of material on the quantitative distribution of abyssal and pelagic fauna, ascertained the productivity of various regions of the ocean, and made summary diagrams of the ocean's hydrobiological zones.

* * *

Before discussing the explorations in the Atlantic Ocean, let us take a brief look at the work done in the marginal seas of the Arctic Ocean—the Greenland Sea and the Norwe-

gian Sea—inasmuch as in the first chapters of this book we spoke primarily about explorations in only the Soviet sector of the Arctic. The study of these seas is important from the standpoint of adding to our knowledge about the natural conditions of the Central Arctic. In addition, they comprise an important commercial fishing, whaling and seal hunting region.

Soviet scientists began studying the Greenland Sea in 1932. Since 1955, studies on a more or less regular basis have been carried on by the Arctic and Antarctic Research Institute, and since 1958, several expeditions have worked in the northern part of the sea every year.

The tasks of the expeditions have included the following: to gather data on the water and ice exchange between the central part of the Arctic Ocean and the Atlantic Ocean; to study the interactions between the atmosphere and the surface of sea waters; to study the characteristics of the distribution of warm Atlantic waters to the north and their influence on the ice conditions in the arctic seas; to determine the seasonal characteristics and yearly fluctuations in the hydrological regime. Expeditions working in the region have also studied the relief of the floor in the northern part of the sea, conducted geological studies and biological observations, studied the chemistry of the waters and gathered data for compiling sailing directions.

Explorations of this kind began with the expedition of 1955 on the ice breaker, the *Litke*. This was the expedition that discovered in the central part of the Arctic Basin, north of Spitsbergen and beyond the limits of the Soviet sector of the Arctic, a depth of 5,449 m (at 82°23′N, 19°31′E), which still stands as the maximum measured depth in the Arctic Ocean (the Litke deep). Then came expeditions on the *Ob* (August-September 1956, in between the first and second antarctic cruises) and on the *Lena* (October-November 1957). There were two expeditions in 1958, one on the *Lena* and the other on a smaller vessel, the *Toros*.

The expeditions listed above explored the northern part of the Greenland Sea and yielded much new information about that area. Depth soundings revealed that the so-called Nansen Sill does not form a continuous bottom rise. It was discovered that the rise is intersected by a deep trench (with depths exceeding 3,000 m) stretching longitudinally between 0° and 3°E and connecting the Nansen Basin in

the Atlantic region of the Central Arctic with the deepwater region of the Greenland Sea. At a depth of 3,000 m the minimum width of the trench is 25 to 30 km. Since it was discovered on the *Lena*, it was named the Lena Trench. It plays a significant role in the water exchange (and heat exchange) between the Greenland Sea and the central part of the Arctic Ocean.

Besides making this very important discovery, the expeditions determined the exact location of the Belgique Bank, gathered new data on the sea depths, and studied the complex relief structure of the continental shelf of Greenland. As a result, new and more accurate navigation charts were compiled. Other work included determining the rate of sedimentation; getting a more accurate picture of the regime of surface and deepwater currents; calculating the amount of warm Atlantic waters that flow into the central part of the Arctic Ocean; describing the thermal regime of the northern part of the Greenland Sea. Chemical and hydrobiological studies produced valuable results, and additional information about ice and weather conditions was gathered.

In 1959, three voyages were made in the northern part of the Greenland Sea on a brand new vessel, the *Storm*. The tasks included making a hydrological survey of the area and conducting hydrochemical, ice and meteorological observations. In the three trips the ship carried out 91 oceanographic stations and travelled a total distance of 10,800 miles, 2,000 of which were in or on the fringes of the polar sea ice. Work on board the *Storm* was impeded by storms and, as was also the case with the *Toros* in 1958, by killer whales, who would make sudden attacks on instruments being pulled out of the water. One killer whale seized an apparatus consisting of a series of barometers, tore the steel rope to which it was attached, and carried it away together with three barometers.

Expeditions of the Arctic and Antarctic Research Institute continued the study of the Greenland Sea in the 1960s.

The Norwegian Sea has also been the object of study by Soviet research vessels. While explorations of the northern part of the Greenland Sea were conducted by the Arctic and Antarctic Research Institute, the study of the Norwegian Sea was handled primarily by expeditions of the Polar Research Institute of Fishing and Oceanography, and partly

also by expeditions of the Soviet Academy of Sciences and other organisations. Ships of the Polar Institute conducted hydrological surveys of the Norwegian Sea in 1954 and 1955. Later they took part in the IGY programme, which also took them into parts of the Greenland Sea. Their work involved hydrological, hydrochemical, biological and geological investigations.

At various times and in various parts of the Norwegian Sea explorations were conducted on the *Professor Mesyatsev*, the *Academician Berg*, the *Rossiya* and the *Sevastopol*.

During the IGY, the *Polyarnik* worked in the northern part of the Norwegian Sea (three voyages), while the *Sevastopol* worked in the central and southern parts (two voyages). Both of these ships carried out work under the IGY programme. In subsequent years, exploration of the sea was conducted by expeditions on the *Sevastopol*, *Tunets*, *Argun*, *Academician Berg*, *Sergei Vavilov* and *Pyotr Lebedev*, and many others.

Important explorations in the marginal seas of the Arctic Ocean were conducted on the laboratory ship, the *Severyanka*, a submarine specially equipped for scientific underwater observations for the purposes of biological and commercial fishing research. The *Severyanka*'s 6th research voyage (December 1960), for example, was devoted specifically to the study of the Norwegian Sea, primarily in the area of Soviet herring fishing. Taking part in the effort was the research ship, the *Professor Mesyatsev*, which acted as the supporting surface ship. The work consisted of systematic observations, including ichthyological observations, the study of plankton, measurement of underwater illumination and assessment of visibility.

Drawing primarily on the results of Soviet explorations, but also using materials gathered by other countries, Soviet scientists compiled a series of important summaries on the underwater relief, currents and bottom sediments of the Norwegian and Greenland seas. It was found that in these two seas and in the adjacent regions of the Atlantic, the Mona Ridge and the Iceland-Jan Mayen Ridge are a direct continuation of the Mid-Atlantic Ridge. The Southern Jan Mayen Ridge was discovered, and the structure of the Iceland Basin was studied in greater detail. Also discovered were a number of seamounts in the Norwegian Sea and numerous canyons on the continental shelf of Iceland.

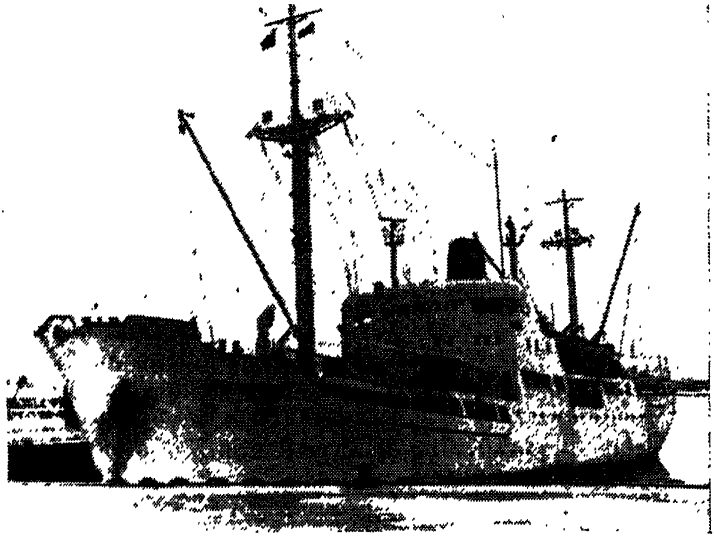
V. M. Litvin drew up a geomorphological map of the Norwegian and Greenland seas. The fishing banks on the Greenland shelf were examined. Biological and commercial fishing studies yielded valuable scientific and practical results.

* * *

Soviet ocean-going expeditions have conducted extensive studies in the waters of the Atlantic Ocean. In contrast to the work done in the Pacific and Indian oceans, emphasis here has been on hydrological and geophysical observations and on studies of the interaction of the ocean and atmosphere; however, the relief, bottom structure and organic life of the ocean have also been studied. Soviet researchers made several discoveries in the Atlantic.

The *Ob* paved the way, as it were, to the Atlantic Ocean for other Soviet research ships when she conducted observations there just before and during the IGY, incidental to her first four antarctic voyages. During the IGY, the *Zarya* conducted magnetic observations in the Atlantic, and the *Sedov* and *Ekvator* worked in the northern part of the ocean. In 1957, an expedition on the *Ekvator* gathered new data on the relief of the Iceland-Shetland Sill, the submarine Rockall Plateau and the Reykjanes Ridge in the northeastern Atlantic. Additional depth sounding data characterising the relief of this area (the Rockall Plateau) were received during the 1st and 3rd voyages of the research ship, the *Mikhail Lomonosov*. We will discuss the voyages of the latter ship in somewhat greater detail, inasmuch as they played approximately the same role in the study of the Atlantic as the voyages of the *Vityaz* played in the Pacific and Indian oceans.

During the IGY, the Marine Hydrophysical Institute of the USSR Academy of Sciences (which later came under the Academy of Sciences of the Ukrainian SSR) began an extensive programme of Atlantic studies on the then new ocean-going research ship, the *Mikhail Lomonosov*, a large capacity vessel with 18 laboratories accommodating a staff of about 70 scientists. The ship's first four voyages, all to the northern part of the Atlantic, took place during the IGY. In subsequent years, she continued working in the Atlantic on a regular basis. During her 8th voyage (1960), other ships took part in the work, and the *Mikhail Lo-*



The *Mikhail Lomonosov*

monosov, as the newest and best equipped of them all, sailed as the flagship.

All the voyages of the *Mikhail Lomonosov* were in the northern and central parts of the Atlantic. Her work in the northern part of the ocean under the IGY research programme yielded extensive material on the interaction of the atmosphere and hydrosphere, surface and deepwater currents, the physical and chemical properties of the water masses, ocean fauna, the composition and nature of suspended matter, bottom sediments and their stratification, and bottom relief. A careful study was made of the relief and structural features of the northern part of the Mid-Atlantic Ridge, the highest peak of which rises 9,000 m above the ocean bed, with the last 2,500 m rising above the surface of the water to form one of the Azores islands. This submarine ridge was discovered more than 100 years ago when the trans-Atlantic telephone cable was being laid, but the detailed study of many of its sections began only in the last decade. The *Mikhail Lomonosov* crossed the ridge several times during her voyages, making continuous depth soundings as she went. Clastic of material containing black basalt and tuff obtained in the vicinity of the ridge gave

evidence of volcanic activity in the area. In 1957, the expedition of the *Mikhail Lomonosov* (1st voyage) observed a spectacular eruption of a submarine volcano near Faial Island (in the Azores). After the eruption, a new island appeared on the surface of the ocean, with an isthmus connecting it to Faial Island.

Fresh data on submarine volcanic activity around the Azores were gathered during the 5th voyage (1959). Exploration of the area between Faial and Flores islands resulted in the discovery of a theretofore unknown seamount rising up to a point only 188 m below the water surface. It was named Mikhail Lomonosov Seamount. Rock samples gathered from the slopes were analysed as clastic ejectamenta (basalts, slag), indicating that the seamount was a submarine volcano. Lava flow showed up on photographs of the ocean bottom there.

The *Mikhail Lomonosov*'s 5th voyage, carried out as part of the international programme of geophysical research, consisted basically of a longitudinal traverse down the middle of the ocean (along the meridian 30°W), from the Greenland-Iceland Rise in the north to the Brazil Basin in the south. This traverse was intersected by another submeridional traverse along the central part of the ocean. The traverse along 30°W cut across the winding Mid-Atlantic Ridge (consisting of the North Atlantic and South Atlantic ridges) four times. Therefore, the expedition was able to obtain much valuable information about the relief of this ridge and the adjacent bottom areas.

The expedition discovered the continuation of the submarine plateau of the Cape Verde Islands, and named it the Krylov Rise, in honour of Academician A. N. Krylov. Here, too, was found evidence of recent submarine volcanism—volcanic tuff, fragments of lava, and volcanic bombs.

At the point where 30°W crosses the equator, the researchers floate da buoy equipped with automatically recording current meters. The measurements showed the presence there of a massive layer of water moving eastward beneath the South Equatorial Current. While it was not determined during this voyage whether such a current exists along the entire Atlantic segment of the equator, the observations made nonetheless laid the basis for discovering a deepwater countercurrent in the Atlantic at the equator.

The 6th voyage of the *Mikhail Lomonosov* (in the autumn of 1959) took place basically in the subtropical and tropical zones of the northern Atlantic (the Gulf Stream and northern trade wind current regions). A double crossing of the ocean yielded important data on its depths and bottom relief structure. A study was made of suspensions, and interesting results were obtained in determining the salinity and dissolved oxygen content of the water at various depths (up to 4,000 m).

During her 7th voyage in the winter and spring of 1960, the *Mikhail Lomonosov* worked in the southern part of the temperate zone and in the subtropical zone. The tasks included studying the physical processes taking place in the water masses of the ocean in the winter and early spring, and studying the interaction between the ocean and atmosphere in the Gulf Stream and North Atlantic current zone and adjacent areas.

Here again, chemical and biological investigations were made, suspended matter was studied, etc. Research was conducted along the traverses, English Channel—Bermuda Islands, and the Great Banks of Newfoundland—the Azores, and along three traverses in the Gulf Stream region. It was the first Soviet expedition to study the central part of the Sargasso Sea. The 8th voyage (summer 1960) took place in roughly the same part of the ocean, excluding the areas adjacent to Newfoundland. At that time, six other ships took part in the work, which was co-ordinated by the Interdepartmental Atlantic Commission. The central task was to study the circulation of the ocean waters in their interaction with atmospheric processes, for which purpose a series of observations of several days duration each were conducted at buoy stations using automatically recording instruments (taking part in these observations, besides the *Mikhail Lomonosov*, were the *Sedov* and the *Ekvator*). Five traverses were made: four in the Sargasso Sea and Gulf Stream zone (all seven ships made seven transverse cuts across the main course of the Gulf Stream), and the fifth, from the Bermuda Islands to the Strait of Gibraltar.

The transverse crossings of the ocean during the 8th voyage yielded new data on the depths and bottom relief. The exact position was determined of the rift valley of the North Atlantic Ridge in the strait between Flores and Faial islands. In the region of the Kelvin Seamount chain in the

North American Basin, where the average depth is around 5,300 m, elevations were discovered with depths of 1,907, 1,941 and 3,141 m.

The 7th and 8th voyages yielded important data on the climate and air circulation, the heat exchange between the ocean waters and the atmosphere, the thermal and dynamic conditions of the atmosphere near the water surface, characteristics of waves, tidal currents, and surface and deep-water currents. An especially great deal of attention was devoted to the Gulf Stream, which plays an exceptionally big role in the movement of the North Atlantic water masses and in the formation of the climate on the continents of the northern hemisphere. It was determined that the current in the open part of the ocean is subject to substantial horizontal shifts. Its maximum velocities are as high as 2 metres per second. Extensive material was gathered on the distribution within the Gulf Stream of water masses with various physical and chemical properties. It was established that the water masses below 2,000 m (in the area under study) are stable, with negligible variations in their properties. Both voyages yielded important information about the Sargasso Sea. The hydrobiological research conducted in the waters of the Gulf Stream and in the region of the Grand Bank of Newfoundland was of important practical value for the fishing industry.

Space does not permit our describing all of the subsequent voyages of the *Mikhail Lomonosov*, which sailed annually and at times even more than once a year. We will therefore say a few words only about a few of them. The 10th voyage, accomplished in 1961, was interesting and important in terms of the scientific results obtained, which in some instances were in the nature of geographical discoveries. During that voyage, the *Mikhail Lomonosov* repeated the hydrological traverse along the meridian of 30°W (without its northern part) which had been made in 1959. Before beginning this traverse, however, the ship worked off the west coast of Africa and then near South America around Brazil. The basic work was done in the tropical waters of the Atlantic and even a little below the Tropic of Capricorn.

The major aim of the voyage was to study the physical processes in the waters and lower layer of the atmosphere in the central part of the Atlantic. The main object of the longitudinal traverse along 30°W was to study the

changes in water circulation and heat transfer that had taken place since the 5th voyage. The plan also included a study of the waters off the west African coast because Soviet fishing vessels work in that area. During the voyage special attention was devoted to deepwater currents. For the first time in the history of Atlantic research, two buoys carrying current meters were anchored at a distance of 24 miles apart. These buoys stood at anchor for up to 60 hours, and operated simultaneously for a period of no less than 26 hours. Besides studying the thermal and dynamic processes in the atmosphere and the ocean, the expedition studied the magnetic and electrical field (precise measurements of magnetic declination to depths of 4,200 m were made under the supervision of Academician V. V. Shuleikin); the propagation of radio waves; the radio activity of the atmosphere, waters and sea bed; physical and chemical processes; the distribution of biogenic substances and plankton; bottom sediments and bottom relief (continuous echo soundings were made for a distance of 12,000 miles).

Temperature and salinity charts were made on the basis of observations along the entire traverse from 30°S to 35°N. The investigations made during that journey confirmed the existence of a deepwater countercurrent at the equator. It was named the Lomonosov deepwater equatorial countercurrent. It represents a huge underwater "river" which carries about 40,000,000 tons of water per second. This is equal to nearly one-half the water masses carried by the Gulf Stream. The current flows with a velocity of up to 120 centimetres per second along the equator in a west to east direction. It is about 400 km wide, with a vertical depth of 200 to 250 m, and its length along the equator is in excess of 4,000 km.* Below the Tropic of Capricorn in the region of the Brazil current discovery was made of another deepwater countercurrent; it was named the Zubov Brazil deepwater countercurrent, in honour of the Soviet oceanologist.

* The Lomonosov deepwater equatorial countercurrent was discovered and explored by expeditions of the Marine Hydrophysical Institute of the Ukrainian Academy of Sciences, basically on the *Mikhail Lomonosov*, but later (in 1969) the eastern part of the current was studied by an expedition of the same institute on a large new vessel, the *Academician Vernadsky*. The oceanologists involved in the discovery and exploration of this current were awarded the State Prize (1970).

That same year (1961), the *Mikhail Lomonosov* accomplished another voyage in the Atlantic, in the region of the Gulf Stream, Sargasso Sea and the northern trade wind current. In the following years (1962-1964) she took part in the programme of joint international studies of the tropical zones of the Atlantic and sailed primarily in the ocean's tropical and equatorial zones, that is, in its central part.

After the IGY, besides the *Mikhail Lomonosov* and the ships that had accompanied her on her 8th voyage, many other ships carried on research in the waters of the Atlantic. The *Ob* also continued her incidental studies. During her 8th and 9th antarctic voyages, discovery and studies were made of a bottom rise in the Angola Basin, south of 11°S and at approximately 0°30′W. It has steep slopes and a relative elevation above the floor of the basin (which is deeper than 5,000 m) of more than 4,800 m. Three smaller rises were discovered further south near the submarine Walvis Ridge.

Working in the northern part of the Atlantic was the research ship, the *Sevastopol*, which during and after the IGY had worked primarily in the southern part of the Norwegian Sea. During her 14th voyage, the *Sevastopol* worked in the vicinity of Newfoundland and made a detailed study of the relief of the Great Bank of Newfoundland in the famous herring fishing region. In the summer of 1960, the Polar Institute of Fishing and Oceanography (PINRO) sent a scientific herring research expedition into the northeastern part of the Atlantic on two ships, the *Boguchar* and the *Balaklava*. The expedition conducted hydrological studies (to determine the distribution of temperature, salinity and flow characteristics of the Gulf Stream); studied the plankton; revealed herring accumulations of particular interest to the fishing industry; and collected specimens of fishes and other marine organisms for the Institute's museum. PINRO explorations continued in 1961 in the western part of the North Atlantic. In the meantime, the research submarine, the *Severyanka*, was also exploring the northern regions of the ocean.

In the autumn of 1960, the Soviet research fleet got two new ships, the *Sergei Vavilov* and the *Pyotr Lebedev*, named after noted Russian physicists. Both ships, each of about 4,600 tons displacement, are equipped for ocean studies employing the latest methods resulting from advances in

physics and electronics. Built for research operations in any ice-free region of the World Ocean, they are also designed for conducting synchronous observations; they carry all the necessary equipment for close interaction and contact during joint operations. They are also equipped with specialised laboratories. Each ship has a hydrological laboratory equipped for taking synchronous measurements jointly with the other. The *Pyotr Lebedev* has laboratories specially equipped for conducting studies in the fields of biology, sound diffraction, hydrochemistry and geology. The *Sergei Vavilov*'s laboratories, except for the hydrological laboratory described above, have basically a geophysical profile. One of them is designed for conducting seismo-acoustical studies on the ocean floor.

At the end of December 1960, after a test run in the Baltic Sea, the ships set out on their first research voyage, which came to be called the First Atlantic Expedition of the USSR Academy of Sciences on the ships, *Sergei Vavilov* and *Pyotr Lebedev*. The tasks of the expedition included testing the ships' instruments and equipment under various climatic conditions, and carrying out comprehensive studies of certain parts of the Atlantic, namely, the equatorial region (near the African coast); the southern region (off the coast of Brazil and Uruguay); the Cape Verde Islands region (near the Tropic of Cancer); and the northern region (west of the English Channel in the main stream of the North Atlantic current). Depth soundings were taken along the entire route. The acoustical method was widely applied in hydrological, hydrobiological and geological studies. The results they produced were compared with the data obtained by trawling and taking bottom core samples. The expedition returned to Leningrad in May 1961.

The second expedition on these ships took place in 1962 (from February to the beginning of August). It carried out comprehensive studies in different regions of the northern half of the Atlantic. The first region (the tropical region) was located 4° north of Puerto Rico; the second (the Gulf Stream region) was several hundred miles south-east of the Nova Scotia Peninsula; the third (the northwestern region) was between the southern tip of Greenland and the Flemish Cap Bank; the fourth (the northeastern region) was between the southern tip of Greenland, the Rockall Bank and Iceland. The fifth region was actually outside the Atlantic, in the

Norwegian Sea (north of the polar circle between Jan Mayen Island and the Lofoten Islands). The studies followed more or less the same programme as in the preceding expedition, also with wide use of acoustical methods. An improved echo sounding technique increased the accuracy of the depth measurements taken throughout the voyage. The stratification of ocean sediment was registered and in the basic regions under study areal surveys of the bottom relief were made. The geologists obtained bottom samples by means of cores and scoops and took underwater photographs of the floor.

Oceanographic research on the *Sergei Vavilov* and the *Pyotr Lebedev* continued in subsequent years. The deepwater regions of the Caribbean Sea were studied by an expedition on the *Academician A. Kovalevsky* (1964). Research on board the ship was conducted jointly with the Academy of Sciences of the Republic of Cuba. The nonmagnetic schooner, the *Zarya*, accomplished a long voyage in the Atlantic in 1964, the year that also saw studies in the northern part of the ocean by the First Atlantic Expedition of the Hydrometeorological Service of the USSR on the *Aisberg*, and the *Okeanograf*. The latter expedition was concerned primarily with current and wave measurement. The biggest waves observed during the expedition's work were 15.6 m high.

In 1966, the Soviet research fleet received a large new vessel, built in the German Democratic Republic and equipped according to designs worked out by the department of marine expeditionary operations of the USSR Academy of Sciences. This ship, the *Academician Kurchatov*, became the flagship of the Soviet research fleet. Although larger (length, 124 m; displacement, 6,500 tons) than her predecessors, she is fast (18 knots) and manoeuvrable. There are 26 scientific laboratories on board. Soon several other research ships of similar design were built, including the *Academician Vernadsky* and the *Dmitri Mendeleyev*, mentioned earlier in connection with its work in the Indian Ocean.

The *Academician Kurchatov* worked primarily in the Atlantic. On her first test voyage (December 1966 to February 1967), she studied mainly the equatorial region west of the Gulf of Guinea, including the Romanche furrow in the system of the Mid-Atlantic Ridge, making investigations on the way along the west coast of Africa in the northern hemisphere. The third voyage (1968) took in

a vast area further south off the west coast of Africa, that is, in the southeastern part of the Atlantic. In the northwestern part of this region discovery was made of an uncharted seamount with a relative height of about 3,000 m. The structure of the Walvis Ridge was examined. It is conjectured that it is a relict of continental structures. During the 5th voyage (1969), the ship visited and explored the regions adjacent to the Great Antilles Islands and the northeastern coast of South America.

In the meantime, research was continuing in the northern part of the Atlantic. In 1968 and 1969, the *Atlantida*, a research ship of the Polar Institute of Fishing and Oceanography, accomplished three voyages with the purpose of studying the North Atlantic current.

On the basis of data gathered by Soviet and foreign expeditions, Soviet scientists drew new bathymetric maps of the Atlantic Ocean, wrote geomorphological and geological descriptions of its floor, and constructed a geomorphological diagram [158]. Materials on the ocean's bottom sediments and suspended substances of primarily its northern part were summarised and published.

The results of research on the interaction of the ocean and the atmosphere in the northern part of the Atlantic, which was conducted under the IGY programme by the Leningrad Hydrometeorological Institute (partly with the use of data gathered by ships of the Polar Institute of Fishing and Oceanography and the *Mikhail Lomonosov*), were published in a special collection of this institute's works [159]. A large number of special works devoted to the research on this and other hydrometeorological and oceanological problems conducted by the Hydrophysical and the Oceanological institutes of the USSR Academy of Sciences have been published. There are also summary works on the distribution of plankton in the Atlantic and its separate regions, and also on the distribution and zonation of deep-water and bottom fauna.

* * *

In 1957, Soviet scientists began studies of the Mediterranean Sea. In 1957 and 1958, the Azov and Black Seas Institute of Fishing and Oceanography carried out fishing explorations in southern part of the Adriatic Sea. And

in 1958, the Sevastopol Biological Station sent its ship, the *Academician A. Kovalevsky*, to the Mediterranean. Four Mediterranean expeditions, carrying out a broad programme of biological and hydrological observations, were conducted on this ship between 1958 and 1960. The first one took place in the summer of 1958 in the Aegean, Ionian and Adriatic seas.

In the summer and autumn of 1959, there were four Soviet ships working in the eastern part of the Mediterranean, one from each of the following: the Sevastopol Biological Station, the Institute of Oceanology of the USSR Academy of Sciences, the Azov and Black Seas Institute of Fishing and Oceanography, and the Sevastopol Marine Observatory. The Institute of Oceanology's ship, the *Academician S. Vavilov* (not the big research ship, the *Sergei Vavilov*, which sailed the Atlantic, but a 382 tons trawler re-equipped for oceanographic work), also worked in the western half of the Mediterranean in the autumn of 1959. She worked there again in the summer of 1960, while the *Academician A. Kovalevsky* and the Marine Observatory's ship conducted studies in the eastern part of the sea. In the winter of 1960-1961, the *Academician A. Kovalevsky* sailed in the western half of the sea, while the *Academician S. Vavilov* operated in its middle and eastern regions. However, the expeditions on the two ships maintained close contact and even followed a practice of interchanging scientific personnel. In the winter and spring of 1962, the *Academician S. Vavilov*'s course covered the entire Mediterranean.

Four Mediterranean expeditions were conducted on board the *Academician S. Vavilov* between 1959 and 1962 (the one in 1959 came under the programme of international geophysical co-operation). The expeditions yielded a vast amount of material on the hydrology and chemistry of the sea, on the distribution of plankton, on the composition and distribution of bottom sediments, and on the relief of the sea bed. Equipped with automatic echo sounders, the ship carried out continuous depth measurements. Photographs of the sea floor were taken, and the thickness of bottom sediments was determined by seismic methods. For the first time in the history of oceanological research underwater television was used, giving a clear picture of the animals and plants on the sea bed at numerous stations. Meteorological observations were also conducted. All in all,

a tremendous volume of research covering the entire sea was conducted, despite frequent storms.

During the first Mediterranean voyage of the *Academician S. Vavilov*, discovery was made of a seamount in the centre of the Tyrrhenian Sea. It rises in excess of 2,500 m above the sea floor, and its crest is 743 m below the water surface. In the course of that same voyage a depth sounding of 4,800 m was obtained at 35°52.7′N and 22°21.1′E—greater than the previously known maximum depth in the Mediterranean. An even deeper sounding was obtained during the 4th voyage: 5,121 m at 36°29.9′N and 21°06.7′E. Detailed soundings there revealed the complicated contours of a small basin stretching in a north-east to south-west direction. The discovery of the maximum depth of the Mediterranean was a significant geographical event.

The 3rd voyage yielded interesting data on the system of trenches located south of the Rhodes-Peloponesus arc. In the region south of Kasos Island, three trenches were discovered, with depths of from 2,550 to 3,920 m and with steep, in places precipitous, slopes. It was later learned that these trenches are part of the single, deep-sea Helen Trench, which apparently is a relict. On its outer side is a rise resembling a marginal ocean sill. The rise has been named the Central Mediterranean sill. Also revealed was a continuous volcanic ridge connecting the Ionian Islands, Crete and Rhodes; that is, it turned out that this was an island arc stretching north of the Helen Trench. The Central Mediterranean Rise was discovered. Finally, what is of particular importance, it was established that the Mediterranean Basin has an oceanic type of the Earth's crust.

In 1965, the 9th Mediterranean expedition on the *Academician S. Vavilov* conducted geophysical studies which yielded important new information on the structure of the sediment layer in the abyssal basins and on the magnetic field of the central and eastern parts of the sea. In 1966, the ship carried an expedition devoted to the study of the bioluminescence of the Mediterranean.

* * *

Having completed our extensive journeyings through the ocean expanses, let us sum up briefly. What were the overall results of Soviet explorations in the World Ocean,

which, beginning with the IGY period, have been conducted in close contact with the efforts of foreign colleagues in a series of co-ordinated programmes?

Over the years of Soviet power and especially in the post-war years, Soviet scientists have made outstanding contributions to the study of the World Ocean, especially of its great depths. Much of their success was due to advances in research techniques, such as the hydroacoustic techniques used in hydrographic and oceanographic research, and especially in studying submarine relief.

While only recently we had almost no reliable information about the bottom relief structure of the World Ocean, the situation is radically different now. New bathymetric maps of all the oceans have been made, giving an entirely new conception of the relief of their beds. Many important elements and forms of the bottom relief of the World Ocean—submarine ridges, rises, seamounts, and basins—have been discovered and mapped by Soviet researchers. As a result of Soviet explorations the cartographic representation of many elements known before or discovered in our times by expeditions on foreign ships has been substantially modified and made more precise. The new bathymetric maps—as well as the use of geophysical methods (seismo-acoustical and others) and underwater photography—have made it possible to make important generalisations about the nature and structure of the ocean floor.

Fundamental differences have been revealed in the structure of the Earth's crust on the continents and in the oceans. It has been established that the marginal parts of seas and oceans, which correspond to the submarine margins of continents, have a continental type of crust, while the deep ocean and sea basins have an oceanic type. The continental crust is thick (up to 30 to 35 km)* and has a three-layered structure, the top layer being sedimentary, the middle layer granitic, and the bottom and most solid layer, basaltic.

The oceanic Earth's crust is relatively thin (typically less than 10 km), and consists of two layers, sedimentary and basaltic. A transitional layer has also been found (the so-called second layer), which suggests the compression of ma-

* On the continents, especially in high mountain regions, its thickness reaches 65-80 km.

rine sediments or the presence of volcanic formations [160].

Soviet marine geologists, together with researchers from other countries, have discovered a new, previously unknown planetary structure, equal in significance to such major elements of the Earth's surface as the continent and the ocean basin. It consists of the mid-oceanic ridges that are found in all of the oceans and are connected with each other to form a single system. An important structural feature of the mid-oceanic ridges are the rift valleys—longitudinal depressions in the ridge crests resulting from deep fractures. These fractures determine the seismicity and linear-type volcanism in the rift valley zones. It was from a rift valley that the *Vityaz* (1964-1965 winter voyage) first dredged clastic material that is believed to be upper mantle rock. Subsequently, similar finds were made frequently.

The once prevalent notion that the ocean floor is smooth has been discarded and the fact of its complicated and varied structure established. The structure is especially complicated in the zones intermediate between the submarine margins of continents and the mid-ocean basins. Here are found the greatest amplitudes of height and depth fluctuation and the greatest relief contrasts on Earth. Next to the deep-sea trenches characteristic of these zones are mighty mountain elevations, the upper parts of which rise above the water in the form of island arcs or peninsulas with lofty volcanic mountains. On the steep slopes of the deepwater trenches processes of bottom sediment slippage and flow take place. The intermediate zones are highly seismic; many intensive earthquakes and seaquakes take place in them, and they contain many active submarine and above-surface volcanoes. These mobile, living zones, located between the submerged edges of continents and the ocean basins, are now regarded as contemporary geosynclines. They are particularly characteristic of the Pacific Ocean, but are also developed in certain marginal parts of the Atlantic and Indian oceans. Of great practical interest for the future are the ore concretions containing iron, manganese, nickel and cobalt that have been found on the ocean floor.

They cover an area amounting to thousands of square miles. It is quite possible that these ores may be extracted from the bottom of the oceans in the future. Scientists also

believe that there are substantial deposits of oil in a number of deep-sea areas.

Great advances have been made in the study of the dynamics and the thermal and chemical characteristics of the waters of the World Ocean; in revealing connections between hydrological and atmospheric processes; and in the study of various geophysical phenomena, such as magnetism, gravity, etc. The picture of surface and deepwater currents has been clarified, and currents never known before have been discovered. This, like the new data on ocean depths and bottom relief, has not only modified specialised maps but is reflected on new general maps.

In connection with their efforts under the IGY programme, Soviet oceanographic research vessels extended their studies to cover the entire World Ocean. The eminent American oceanographer, R. Revell, who visited the *Vityaz* in December 1958, left an entry in the ship's log in which he noted that the Soviet contribution to the International Geophysical Year would be remembered by many generations of scientists [161].

As concerns the biological research that has been conducted, special note should be made of the study of deep-sea fauna. Diagrams indicating the geographic distribution of the World Ocean's deep-sea fauna have been produced for the first time. The ecological features of the fauna and the vertical zonation of its distribution have been brought to light. Important conclusions have been reached regarding the density of the biomass at great depths and in the surface layers of the ocean. It has been noted that it increases markedly at the junction of warm and cold waters, that is, in frontal zones. This knowledge is of great practical value to fishing.

A major theoretical proposition on which Soviet oceanologists base their research is the concept of the interconnection between the various processes in the ocean—biological, hydrological, chemical, geological, etc.—all of which form a single whole. The quantitative relations between these processes and the corresponding components of the ocean environment account for the substantial qualitative differences in various regions of the World Ocean. The productivity and fishing value of the various regions depend on this. In its time, the concept of the undivided nature of the ocean (S. I. Vavilov and V. G. Bogorov) underlay the

foundation of the Institute of Oceanology of the USSR Academy of Sciences*.

A large group of Soviet scientists and specialists—hydrographers, oceanographers and cartographers—compiled a *Sea Atlas*, in which one can find any point on the coasts and any little island in the ocean. The atlas indicates the depths, currents, winds, and the distribution of temperature and salinity in the oceans and seas [162]. However, this major work was published prior to the studies made under the IGY and later programmes, so that it does not reflect the latest data. The findings of later research were partially reflected on maps in the *Physico-Geographic Atlas of the World*, published in 1964.

The co-ordination of all oceanographic research in the USSR is handled by the interdepartmental Oceanographic Commission of the Presidium of the USSR Academy of Sciences. In the last decade, several international oceanological associations have come into being: the International Consultative Committee on Marine Science, under the auspices of UNESCO; the Special Committee on Oceanographic Research and the International Committee on Deep Sea Research, under the auspices of the International Council of Scientific Unions. The International Council for the Exploration of the Sea, which has been in existence for more than 50 years, has recently increased its activity. International contacts and ties in the study of the oceans and seas are of tremendous importance to our common endeavour to learn the secrets of the World Ocean and to use its resources for the benefit of mankind.

* This institute was created in January 1946 on the basis of the Laboratory of Oceanology of the USSR Academy of Sciences. The first director of the institute was Academician P. P. Shirshov (who had also been the director of the Laboratory of Oceanology, organised in 1941).

BIBLIOGRAPHY

1. S. Obruchev, *In the Eastern Arctic by Plane*, Leningrad, 1934, p. 140.

2. L. S. Berg, "Russian Discoveries in the Pacific". In the collection, *The Pacific Ocean. Russian Scientific Research*, Leningrad, 1926, p. 2; similar text in: L. S. Berg, *On the History of Russian Geographical Discoveries*, Moscow-Leningrad, 1949, p. 147.

3. V. I. Lenin, *Collected Works*, Vol. 36, p. 320.

4. K. A. Salishchev, *Fundamentals of Cartography, History and Cartographic Materials*, Moscow, 1948, p. 200.

5. N. N. Zubov, *In the Centre of the Arctic*, Moscow-Leningrad, 1948, pp. 92-93; L. A. Zenkevich, *Exploration of the World Ocean*, Moscow, 1961, pp. 2-4.

6. N. N. Zubov, *op. cit.*, p. 92.

7. A. E. Fersman, "V. I. Lenin and the Study of the Productive Forces of the USSR", *Vestnik Akademii Nauk SSSR*, 1940, No. 4-5, pp. 66, 73.

8. A. A. Borzov, *Geography in the USSR over 20 Years. Geographical Works*, Moscow, 1954, p. 351.

9. *Atlas of the World*, A. F. Marx Publishers, St. Petersburg. 1916.

10. G. A. Ushakov, *Over Untrodden Land*, Moscow-Leningrad, 1951, p. 7.

11. *Ibid.*, p. 11.

12. *Ibid.*, p. 94.

13. *Ibid.*, p. 268.

14. N. N. Urvantsev, *Severnaya Zemlya. A Brief Outline of Exploration*, Leningrad, 1933, pp. 7-8.

15. G. A. Ushakov, *op. cit.*, p. 389.

16. N. N. Zubov, *op. cit.*, p. 103.

17. V. Y. Vize, *The Seas of the Soviet Arctic*, pp. 164-165.

18. I. D. Papanin, *Life on an Ice Floe. Diary*, 2nd ed., Moscow, 1940, pp. 37, 46, 52, 74, 76, 78 (5th ed., Moscow, 1966, pp. 39, 47, 53, 73, 76, 78).

19. N. N. Zubov, *op. cit.*, p. 114.

20. *Ibid.*, p. 130.

21. V. F. Burkhanov, "The Origin of Ice Islands in the Arctic", *Problemy Geografii*, No. 36, 1954, p. 27.

22. A. F. Treshnikov, *One Year on an Ice Floe*, Moscow, 1956, p. 44.

23. A. F. Laktionov, V. V. Frolov, *On Drifting Ice Fields*, 1955, p. 52.

24. A. F. Treshnikov, *op. cit.*, p. 61.

25. A. F. Laktionov, V. V. Frolov, *op. cit.*, pp. 48-50.

26. A. F. Treshnikov, *op. cit.*, p. 92.

27. Y. Gakkel, "The Submarine Lomonosov Ridge", *Vokrug Sveta*, 1954, No. 11, pp. 5-6.

28. A. Middendorf, *A Journey to the North and East of Siberia*, Part I, St. Petersburg, 1860, p. 26.

29. *Ibid.*

30. A. I. Tolmachev, "The Taimyr Expedition of the USSR Academy of Sciences", *Reports of the USSR Academy of Sciences*, 1929, pp. 183-186; A. I. Tolmachev, "Preliminary Report on the Work of the Taimyr Expedition of the USSR Academy of Sciences in 1928", *Transactions of the Polar Commission of the USSR Academy of Sciences*, No. 1, Leningrad, 1930, pp. 16-17, 24.

31. E. Velichko, "A Year on the Taimyr 'Blank Space'", *Geografia v shkole*, 1948, No. 6, pp. 33-34.

32. A. I. Kosoy, *O nthe East Coast of the Taimyr Peninsula*, Moscow, 1944, pp. 47-48.

33. *Ibid.*, p. 49.

34. *Ibid.*, p. 95.

35. *Ibid.*, p. 97.

36. *Ibid.*, p. 98.

37. S. Obruchev, *In the Unknown Mountains of Yakutia. The Discovery of the Chersky Range*, Moscow-Leningrad, 1928, p. 246.

38. *Ibid.*, p. 247.

39. *Ibid.*

40. S. Obruchev, *From Yakutsk to the Bering Strait*, Moscow-Leningrad, 1940, pp. 22-23.

41. *Ibid.*, p. 30; S. Obruchev, *To Unexplored Territories*, Moscow, 1954, p. 38.

42. *Ibid.*, p. 33 (1954 ed., p. 41).

43. *Ibid.*, p. 34 (1954 ed., p. 42).

44. *Ibid.*, pp. 35-36 (1954 ed., p. 43).

45. S. Obruchev, *In the Unknown Mountains of Yakutia*, p. 116.

46. *Ibid.*, p. 165 (1954 ed., p. 65).

47. Quote from S. Obruchev, *In the Unknown Mountains of Yakutia*, p. 242.

48. S. Obruchev, *From Yakutsk to the Bering Strait*, p. 197.

49. *Ibid.*, p. 136.

50. S. Obruchev, *Kolyma Country. Two Years of Wandering*, Moscow, 1933, p. 129.

51. S. Obruchev, *From Yakutsk to the Bering Strait*, p. 180.

52. S. Obruchev, *Kolyma Country*, p. 169.

53. *Ibid.*, pp. 168-170.

54. L. Berman, "The Riddle of the White Mountains", *Vokrug Sveta*, 1947, No. 4, pp. 47-48.

55. L. Berman, "Recent Glaciation in the Upper Reaches of the Indigirka River", *Problemy Geografii*, 1947, No. 4, p. 35.

56. A. P. Vaskovsky, "Recent Glaciation in the North-East of the USSR", *Materials on the Geology of the North-East of the USSR*, 1955, No. 9, pp. 77, 80.

57. V. A. Obruchev, *Selected Works on the Geography of Asia*, Vol. II, Moscow, 1951, pp. 100-137 (the article, "New Data on the Yablonovoi and Stanovoi Ranges").

58. S. Obruchev, *In the Eastern Arctic by Plane*, Leningrad, 1934, p. 4.

59. *Ibid.*, pp. 182, 184.

60. A. N. Trotsky, "On the Behaviour of the Crater of the Klyuchevsky Volcano in 1935", *State Geographic Society News*, Vol. 69, 1937, p. 973; L. S. Berg, *On the History of Russian Geographical Discoveries*, Moscow-Leningrad, 1949, pp. 452-453.

61. I. M. Suslov, *The Olenek River*, Leningrad, 1937, pp. 4-5.

62. G. Fedoseyev, *We Go Through the Eastern Sayan Mountains*, Novosibirsk, 1951.

63. S. Obruchev, *In Central Asia*, Moscow, 1965, pp. 67, 78, 95, 112-124.

64. M. V. Tronov, "Recent Glaciation in the Altai", *Transactions of the Second All-Union Geographical Congress*, Vol. 1, Moscow, 1948, p. 286; M. V. Tronov, *Glaciation in the Altai*, Moscow, 1949.

65. E. Murzayev, *Along Unbeaten Tracks. A Geographer's Notes*, Moscow, 1954, p. 169.

66. P. N. Rapasov, "Survey of the Khan Tengri Area", *Geografia shkole*, 1946, No. 1, p. 42.

67. *Ibid.*, p. 43.

68. *All-Union Geographical Society News*, Vol. 80, 1948, p. 206. Author of comment, S. V. Kalesnik.

69. S. S. Schultz, *An Analysis of the Recent Tectonics and Relief of Tien Shan*, Moscow, 1948.

70. "Materials on the Study of Glaciation in the Mountains of Central Asia", *Transactions of the Hydrometeorological Section of the Central Asian Meteorological Institute*, Vol. I, Tashkent, 1927.

71. *Ibid.*, p. 18.

72. *Transactions of the Pamir Expedition of 1928*, 1st ed., General Report, Leningrad, 1930, p. 6.

73. I. G. Dorofeyev, "Over the 'Blank Space' of the Western

Pamirs", *Conquered Heights*, Annual of Soviet Alpinism, 1951; Moscow, 1952, p. 406.

74. *Ibid.*

75. *Ibid.*, p. 408.

76. N. L. Korzhenevsky, "On the Morphology and Hypsometry of the USSR Academy of Sciences Range", *Transactions of the Geological Institute of the Academy of Sciences of the Uzbek SSR*, Tashkent, 1948, p. 67.

77. V. F. Suslov, et al., *A Station Above the Clouds*, Moscow, 1961.

78. *Ibid.*, p. 233.

79. *The Fedchenko Glacier*, Vol. 1, Tashkent, 1962.

80. S. I. Klunnikov, "The Southwestern Pamirs. Latest Geographical Discoveries", *Transactions of the Tajik-Pamir Expedition*, Geography Series, Moscow-Leningrad, 1937, pp. 3-4.

81. *Ibid.*, pp. 5-6.

82. *Ibid.*, p. 7.

83. A F. Sosedko, "The Kyzyl Kum, Yesterday and Today", *Priroda*, 1939, No. 7, p. 44.

84. *Ibid.*, p. 45.

85. E. M. Murzayev, *op. cit.*, p. 52.

86. V. N. Kunin, *The Local Waters of the Desert and the Problems of Their Utilisation*, Moscow, 1959.

87. E. M. Murzayev, *op. cit.*, p. 58.

88. A. L. Yanshin, *The Geology of the Northern Aral Sea Area*, Moscow, 1953.

89. B. N. Gorodkov, "The Polar Urals at the Upper Reaches of the Sobi and Voikara Rivers", *USSR Academy of Sciences News*, Vol. 20, No. 9, 1926, p. 746.

90. G. D. Richter, "Orographic Regions of the Kola Peninsula", *Transactions of the Institute of Physical Geography of the USSR Academy of Sciences*, issue 19, Moscow-Leningrad, 1936.

91. M. N. Karbasnikov, "Wind Belt", *Works on the Geography of the Northern European Part of the USSR*, Leningrad, 1940, p. 5.

92. D. N. Anuchin, *Geographical Works*, Moscow, 1954, p. 333.

93. L. S. Berg, *One Hundred Years of the All-Union Geographical Society*, Moscow-Leningrad, 1946, pp. 223-224; P. K. Kozlov, "Around Mongolia", *Our Country*, 1941, No. 4, pp. 31-35; P. K. Kozlov, "A Journey to Mongolia in 1923-1926", Diaries, prepared by E. V. Kozlova, *Notes of the All-Union Geographical Society*, New Series, Vol. 7, Moscow, 1949.

94. *Northern Mongolia*, Vols. I-III, Leningrad, 1926-1928.

95. E. M. Lavrenko and I. F. Shulzhenko, "Brief Review of the Work of the Mongolian Agricultural Expedition of the USSR Academy of Sciences, 1947-1952", *All-Union Geographical Society News*, Vol. 94, 1962, p. 175. This article contains a list of publications on the materials of the expedition.

96. A. K. Rozhdestvensky, *Dinosaur Hunting in the Gobi Desert*, Moscow, 1957, p. 175.

97. I. A. Yefremov, *The Road of Winds (Gobi Notes)*, Moscow, 1956, pp. 157-158.

98. E. M. Murzayev, *The Mongolian People's Republic*, Moscow, 1952; E. M. Murzayev, *Along Unbeaten Tracks*, Moscow, 1954.

99. E. M. Murzayev, *The Natural Features of Sinkiang and the Formation of the Deserts of Central Asia*, Moscow, 1966; E. M. Murzayev, *Travels Without Adventure and Romance. A Geographer's Notes*, Moscow, 1962.

100. N. T. Kuznetsov, *Tracking Wandering Rivers. A Hydrologist's Notes*, Moscow, 1965.

101. *The Natural Condition of Sinkiang*, Moscow, 1960; *Kunlun and Tarim. Brief Descriptions of Their Natural Features*, Moscow, 1961.

102. M. P. Petrov, *30,000 Kilometres Over the Deserts of Central Asia. Soviet Expeditions in 1959*, Moscow, 1962, p. 226.

103. M. P. Petrov, *The Deserts of Central Asia*, Vols. 1, 2, Moscow-Leningrad, 1966, 1967.

104. N. T. Kuznetsov, *op. cit.*, pp. 4-5.

105. *Ibid.*, p. 23.

106. V. M. Friedland, *The Natural Features of North Vietnam*, Moscow, 1961; V. M. Friedland, *The Soils and Crust of Weathering of the Humid Tropics (On the Example of North Vietnam)*, Moscow, 1964.

107. E. G. Chernyakovskaya, "Seistan. Travel Notes", *The State Russian Geographical Society News*, Vol. 60, 1928; L. S. Berg, *One Hundred Years of the All-Union Geographical Society*, 1946, pp. 235-236.

108. N. I. Vavilov, "The Wheats of Abyssinia", *Selected Works*, Vol. III, Moscow-Leningrad, 1962; N. I. Vavilov, *Five Continents*, Moscow, 1962; L. S. Berg, *One Hundred Years of the All-Union Geographical Society*, pp. 215-216.

109. N. M. Fedorovsky, *In the Land of Diamonds and Gold. Travels Through Southern Africa*, Moscow-Leningrad, 1936; I. P. Gerasimov, *My Travels Abroad*, Moscow, 1958, pp. 5-29; I. P. Gerasimov, "Geographical Observations in Central and Southern Africa", in the book: *Brief Descriptions of the Physical Geography of Foreign Countries*, 1959; G. V. Bogomolov, *Forty Days in Northern Africa*, Minsk, 1956; M. B. Gornung, "A Description of the Wadi of Northern Algeria", *USSR Academy of Sciences News*, Geography Series, 1953; No. 5; P. A. Baranov, *In Tropical Africa. A Botanist's Notes*, Moscow, 1956; A. L. Kursanov, *Through France and Western Africa*, Moscow, 1956.

110. B. F. Dobrynin, "Mexico. A Geographical Study", *Zemlevedeniye*, Books 1-2 and 3-4, 1926.

111. *National Atlas of Cuba*, Havana, 1970 (published in Spanish and Russian).

112. Y. N. Voronov, "The Weather in Colombia" in the series, "Nature and People", a monthly supplement to the magazine *Vestnik Znaniya*, Book 5, Leningrad, 1929.

113. L. S. Berg, *One Hundred Years of the All-Union Geographical Society*, pp. 216-218; N. I. Vavilov, "The Great Agricultural Cultures

of Pre-Columbian America and Their Mutual Relations", *State Geographical Society News*, Vol. 71, 1939; N. I. Vavilov, *Five Continents*, Moscow, 1962.

114. L. E. Rodin, *Five Weeks in South America*, Moscow, 1954; I. P. Gerasimov, *My Travels Abroad*, 1959, pp. 93-142 (*Brazilian Diaries*—1956); I. P. Gerasimov, "Geographical Observations in Brazil", in the book, *Brief Descriptions of the Physical Geography of Foreign Countries*, 1959; S. V. Kalesnik, *In Brazil. Travel Sketches*, Moscow, 1958.

115. A. M. Gusev, *In the Snows of the Antarctic*, Moscow, 1961, p. 101.

116. P. A. Shumsky, "Soviet Glaciological Research in the Antarctic", in the collection, *Seismological and Glaciological Research During the IGY*, Moscow, 1959, p. 77.

117. A. F. Treshnikov, *Ice Bound*, Moscow, 1959, p. 63.

118. M. A. Kuznetsov, *Under the Roofs of Mirny*, Moscow-Leningrad, 1964, pp. 124-125, 135-144.

119. *Ibid.*, p. 249.

120. A. F. Treshnikov, *The History of the Discovery and Exploration of Antarctica*, Moscow, 1963, p. 309.

121. K. Zakiyev, *The Queen of Cold. From a Geographer's Diary*, Rostov-on-Don, 1961, p. 60.

122. *Ibid.*, p. 61.

123. *Ibid.*, p. 78.

124. *Ibid.*, p. 86.

125. *Ibid.*, p. 91.

126. M. G. Ravich, *The Warmed Land, In the Mountains of Antarctica*, Moscow, 1961, pp. 97-98; Y. A. Kruchinin, *The Shelf Ice of Queen Maud Land*, Leningrad, 1965, pp. 143-145.

127. *Ibid.*, p. 101; A. V. Noudelman, *Soviet Expeditions to the Antarctic, 1958-1960*, Moscow, 1960, p. 11.

128. *Ibid.*, p. 103.

129. *Ibid.*, p. 119-120.

130. A. G. Dralkin, *In the World of Cold*, Moscow, 1961, p. 115.

131. *Ibid.*, p. 140.

132. *Ibid.*, p. 144.

133. A. V. Noudelman, *Soviet Expeditions to the Antarctic, 1959-1961*, Moscow, USSR Academy of Sciences Publishing House, 1962, pp. 145-148; A. F. Treshnikov, *op. cit.*, pp. 354-359.

134. A. V. Noudelman, *Soviet Expeditions to the Antarctic, 1958-1960*, p. 86.

135. P. D. Astapenko, *A Journey to the Island of Four Volcanoes*, Moscow, 1964, pp. 34-35.

136. M. M. Somov, "The Eighth Seasonal Expedition", *SAE Information Bulletin*, 1964, No. 46, p. 7.

137. S. F. Dukhanin, "A Hurricane in the Mountains of Enderby Land", *SAE Information Bulletin*, 1964, No. 46, p. 60.

138. G. Protsenko, "Antarctic Spring. Report from the Sixth Continent, *Pravda*, December 11, 1963.

139. *List of Geographical Names in East Antarctica*, Leningrad, 1959.

140. A. P. Kapitsa, *The Subglacial Relief of Antarctica* (Doctoral dissertation), Moscow, 1965, p. 14.

141. A. P. Kapitsa, *Is Antarctica a Continent?* Moscow, 1961, p. 44.

142. A. P. Kapitsa, *The Subglacial Relief of Antarctica*, pp. 15-17.

143. *SAE Information Bulletin*, 1970, No. 78, p. 110.

144. K. K. Markov, "To Antarctica", *Priroda*, 1956, No. 8, p. 68.

145. K. K. Markov, "The Paleogeography of Antarctica", *Antarctica. Report of the Interdepartmental Commission on the Study of Antarctica*, Moscow, 1963, p. 48.

146. V. M. Kotlyakov, "The Snow Cover of Antarctica and Its Role in the Recent Glaciation of the Continent", *Results of Research Under the IGY Programme (Glaciology)*, No. 7, Moscow, 1961, p. 212.

147. V. G. Kort, E. S. Korotkevich, V. G. Ledenev, "The Boundaries of the Southern Ocean", *SAE Information Bulletin*, 1964, No. 50.

148. *The Atlas of Antarctica*, Vol. 1, Moscow-Leningrad, 1966; Vol. 2, Leningrad, 1969.

149. G. B. Udintsev, "Studies of the Floor Relief of Seas and Oceans. Advances in the Study of Ocean Depths (Biological and Geological)", *Science and Achievements in Oceanology*, 1, Moscow, 1959, p. 46.

150. V. G. Kort, "Explorations of the Far Eastern Seas and the Pacific Ocean Conducted by the Institute of Oceanology of the USSR Academy of Sciences in 1949-1954", in the collection, "Oceanological Research in the Northwestern Part of the Pacific Ocean". *Works of the Oceanographical Commission*, Vol. 3, Moscow, 1958, pp. 9-10.

151. E. M. Kreps, *On the "Vityaz" to the Islands of the Pacific Ocean*, Moscow, 1959, p. 109.

152. *Ibid.*, p. 110.

153. "The Secrets of the World Ocean", *Pravda*, January 20, 1966.

154. O. K. Leontyev, *A Short Course in Marine Geology*, 1963, pp. 381-391.

155. E. M. Kreps, *The "Vityaz" in the Indian Ocean*, Moscow, 1963, pp. 53-63.

156. Quote from E. M. Kreps, *The "Vityaz" in the Indian Ocean*, p. 7.

157. V. F. Kanayev, N. A. Marova, "Bathymetric Map of the Northern Part of the Indian Ocean", collection of articles, *Oceanological Research*, No. 13, Moscow, 1965; I. M. Belousov, "Bathymetric Map of the Northwestern Part of the Indian Ocean", *ibid.*

158. L. K. Zatonsky, "A New Bathymetric Map of the Atlantic Ocean", *ibid.*; N. A. Grabovsky, R. H. Greku, A. P. Metalnikov,

"Some Geomorphological Features of the Atlantic Ocean Floor Relief Along the Thirtieth Meridian from the North Polar Circle to the Tropic of Capricorn", *Okeanologia*, Vol. 1, 1961; O. K. Leontyev, *A Short Course in Marine Geology*, pp. 353-354, 379, 391-398.

159. "Explorations of the Northern Part of the Atlantic Ocean", *Transactions of the Leningrad Hydrometeorological Institute*, 1961.

160. O. K. Leontyev, *op. cit.*, p. 76.

161. N. N. Gorsky, *The Secrets of the Ocean*, Moscow, 1960, pp. 205-206.

162. *Sea Atlas.* Vols. 1 and 2, 1950 and 1953.